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Background Information for Proposed Standards

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Standards of Performance for the control of VOC emissions from petroleum dry cleaning facilities are being proposed under the authority of section 111(b) of the Clean Air Act. These standards apply to new, modified, or reconstructed petroleum dry cleaning facilities, the construction or modification of which began on or after the date of proposal. This draft document contains background information, environmental and economic impact assessments, and the rationale for the standards as proposed under 40 CFR Part 60, Subpart JJJ.

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Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

November 1982

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ENVIRONMENTAL PROTECTION AGENCY

Background Information and Draft Environmental Impact Statement for Petroleum Dry Cleaners

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12/10/82

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(Date)

1. The proposed standards of performance would limit emissions of Volatile Organic Compounds from new, modified, and reconstructed petroleum dry cleaners. Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, directs the Administrator to establish standards of performance for any category of new stationary source of air pollution that ". . . causes or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Transportation, Agriculture, Commerce, Interior, and Energy; the National Science Foundation; the Council on Environmental Quality; members of the State and Territorial Air Pollution Program Administrators; the Association of Local Air Pollution Control Officials; EPA Regional Administrators; and other interested parties.

3. The comment period for review of this document is 60 days. Mr. Fred Porter may be contacted regarding the date of the comment period.

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TABLE OF CONTENTS

Section		Page
1	SUMMARY	1-1
	1.1 Regulatory Alternatives	1-1
	1.2 Environmental Impact	1-2
	1.3 Economic Impact	1-2
2	INTRODUCTION	2-1
	2.1 Background and Authority for Standards	2-1
	2.2 Selection of Categories of Stationary Sources	2-5
	2.3 Procedure for Development of Standards of Performance	2-6
	2.4 Consideration of Costs	2-8
	2.5 Consideration of Environmental Impacts	2-9
	2.6 Impact on Existing Sources	2-10
	2.7 Revision of Standards of Performance	2-11
3	PETROLEUM DRY CLEANING INDUSTRY	3-1
	3.1 Industry Description	3-1
	3.2 Process Description	3-2
	3.3 Emission Sources	3-6
	3.4 Baseline Emissions	3-27
	3.5 References for Chapter 3	3-32
4	EMISSION CONTROL TECHNIQUES	4-1
	4.1 Dryer Emission Control Techniques	4-1
	4.2 Filtration Emission Control Techniques	4-26
	4.3 Fugitive Emission Control Techniques	4-27
	4.4 References for Chapter 4	4-31
5	MODIFICATION AND RECONSTRUCTION	5-1
	5.1 Summary of Modification and Reconstruction Provisions	5-1

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TABLE OF CONTENTS (concluded)

Section Page

5.2 Petroleum Solvent Dry Cleaning Affected Facilities. 5-3

6 MODEL PLANTS AND REGULATORY ALTERNATIVES 6-1

6.1 Model Plants. 6-1

6.2 Regulatory Alternatives 6-4

6.3 References for Chapter 6. 6-7

7 ENVIRONMENTAL IMPACTS. 7-1

7.1 Air Impacts 7-1

7.2 Water Impacts 7-6

7.3 Solid Waste Impacts 7-11

7.4 Energy Impacts. 7-11

7.5 References for Chapter 7. 7-15

8 COST ANALYSIS. 8-1

8.1 Basis for Capital Costs 8-1

8.2 Basis for Annualized Costs. 8-3

8.3 Cost Analysis of Regulatory Alternatives. . . . 8-12

8.4 Other Cost Considerations 8-27

8.5 References for Chapter 8. 8-30

9 ECONOMIC ANALYSIS 9-1

9.1 Industry Characterization 9-2

9.2 Economic Impact of Regulatory Alternatives. . . 9-29

9.3 Potential Socioeconomic and Inflationary Impacts 9-56

9.4 References for Chapter 9. 9-59

APPENDIX A. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT . A-1

APPENDIX B. INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS . . . B-1

APPENDIX C. EMISSION SOURCE TEST DATA. C-1

APPENDIX D. ENVIRONMENTAL AND COST IMPACTS OF EXEMPTION LEVEL AS APPLIED TO REGULATORY ALTERNATIVE III D-1

LIST OF FIGURES

Figure		Page
3-1	Petroleum dry cleaning plant flow diagram	3-3
3-2	Typical dry cleaning equipment in existing plants . .	3-5
3-3	Cartridge filtration system schematic	3-13
3-4	Solvent emissions for filter cartridges as a function of drainage time	3-16
3-5	Batch flow settling tank.	3-19
3-6	Continuous flow settling tank	3-20
3-7	Vacuum still diagram.	3-23
4-1	Solvent vapor flow diagram for a recovery dryer . . .	4-2
4-2	Operating cycles of the existing recovery dryer . . .	4-4
4-3	Solvent recovery and concentration curves for the recovery dryer.	4-11
4-4	Carbon adsorption system schematic.	4-18
4-5	Adsorption and desorption	4-19
9-1	Relationship of net annualized costs for Alternative III to plant throughput assuming an amortization period of five years	9-50
C-1	Recovery and concentration curves for a high-emission recovery dryer load, plant B.	C-8
C-2	Recovery and concentration curves for a low-emission recovery dryer load, plant B.	C-9

LIST OF FIGURES (concluded)

Figure		Page
C-3	Recovery and concentration curves for a recovery dryer with test-average emissions, plant B.	C-10
C-4	Recovery and concentration curves for a low-emission recovery dryer load, plant C.	C-15
C-5	Recovery and concentration curves for a high-emission recovery dryer load, plant C.	C-16
C-6	Recovery and concentration curves for a recovery dryer load with emissions approximately equal to the overall test average, plant C	C-18
C-7	Solvent emissions for filter cartridges as a function of drainage time, plant D	C-20
C-8	Carbon adsorption system schematic, plant E	C-27

LIST OF TABLES

Table		Page
1-1	Assessment of Environmental, Energy, and Economic Impacts for Each Regulatory Alternative Considered for Petroleum Solvent Dry Cleaning Plants.	1-3
3-1	Physical and Chemical Properties of Hydrocarbon Dry Cleaning Solvents	3-7
3-2	Baseline VOC Emission Rates.	3-31
4-1	Summary of Recovery Dryer Test Results	4-7
6-1	Model Plant Parameters	6-3
6-2	Model Plant Emission Rates for Regulatory Alternatives I, II, and III	6-5
7-1	Annual VOC Emission Impacts of the Three Regulatory Alternatives in the Five Model Plants.	7-2
7-2	Projected Number of Affected Plants Over Ten Years Following Proposal of the Standards . . .	7-4
7-3	Cumulative Nationwide VOC Impacts of the Five Model Plants Under Three Regulatory Alternatives For Ten Years	7-5
7-4	Annual Water Pollution Impacts of Emission Control in Five Model Plants	7-8
7-5	Cumulative Nationwide Water Impacts of Emission Control in Five Model Plant Categories Under Regulatory Alternative III For Ten Years	7-10
7-6	Annual Energy Impacts of Three Regulatory Alternatives in Five Model Plants	7-12
7-7	Cumulative Nationwide Energy Impacts in Five Model Plants Under Three Regulatory Alternatives For Ten Years	7-14

LIST OF TABLES (continued)

Table		Page
8-1	Affected Equipment Costs in Five Model Plants. . . .	8-2
8-2	Capital Costs for a New Small Commercial Model Plant.	8-4
8-3	Capital Costs for a New Medium Commercial Model Plant.	8-5
8-4	Capital Costs for a New Large Commercial Model Plant.	8-6
8-5	Capital Costs for a New Small Industrial Model Plant.	8-7
8-6	Capital Costs for a New Large Industrial Model Plant.	8-8
8-7	Calculation of Annualized Costs of Affected Dry Cleaning Equipment	8-9
8-8	Operating Parameters for Standard and Recovery Dryers	8-10
8-9	Capital and Annualized Costs of Control in a Small Commercial Model Plant	8-14
8-10	Capital and Annualized Costs of Controls in a Medium Commercial Model Plant	8-15
8-11	Capital and Annualized Costs of Controls in a Large Commercial Model Plant	8-16
8-12	Capital and Annualized Costs of Controls in a Small Industrial Model Plant	8-17
8-13	Capital and Annualized Costs of Controls in a Large Industrial Model Plant	8-18
8-14	Summary of the Incremental Annualized Cost, Emission Reduction, and Cost Effectiveness of Regulatory Alternative III in Three Model Plants . .	8-21
8-15	Nationwide Cost Analysis of Three Regulatory Alternatives in Five Model Plants Projected for Five Years after Proposal	8-24

LIST OF TABLES (continued)

Table		Page
8-16	Nationwide Cost Analysis of Three Regulatory Alternatives in Five Model Plants Projected for Ten Years after Proposal	8-25
9-1	Kinds of Cleaning Firms, as Classified by the Census Bureau	9-3
9-2	Plant and Revenue Trends in the Commercial Sector of the Dry Cleaning Industry (SIC 7216).	9-6
9-3	Distribution of Commercial Dry Cleaners (SIC 7216) by Number of Employees, 1977	9-7
9-4	Plant and Revenue Trends in the Industrial Laundry and Dry Cleaning Sector (SIC 7218)	9-9
9-5	Distribution of Industrial Cleaners (SIC 7218) by Number of Employees, 1977	9-10
9-6	Producers of Petroleum Solvent Producers	9-11
9-7	Manufacturers of Petroleum Washers and Dryers . . .	9-12
9-8	Manufacturers of Stills and Filters	9-13
9-9	Regional Trends in Revenues at Commercial Dry Cleaners and Industrial Cleaners (SIC 7216 and 7218), 1972-1977	9-15
9-10	Proportions of Commercial Dry Cleaners Using Petroleum Solvent, by State and Region	9-16
9-11	Dry Cleaning and Consumer Price Indices, 1954-1981 .	9-17
9-12	Concentration of Revenues Among Major Firms: Combined Laundry, Cleaning, and Other Garment Services (SIC 721), 1972	9-19
9-13	Franchising in Laundry and Dry Cleaning Services: Distribution by Number of Plants, 1977	9-20
9-14	U.S. Imports of Dry Cleaning Machines, Excluding Coin-Operated Machines, 1977	9-21
9-15	Income and Cost Ratios Used as the Basis for Model Plant Pro Forma Cash Flows	9-22
9-16	Affected Facilities at Small Commercial Dry Cleaners During First Five Years After Proposal	9-24

LIST OF TABLES (continued)

Table		Page
9-17	Affected Facilities at Medium Commercial Dry Cleaners During First Five Years After Proposal . .	9-25
9-18	Affected Facilities at Large Commercial Dry Cleaners During First Five Years After Proposal . .	9-26
9-19	Affected Facilities at Small Industrial Dry Cleaners During First Five Years After Proposal . .	9-27
9-20	Affected Facilities at Large Industrial Dry Cleaners During First Five Years After Proposal . .	9-28
9-21	Differential Cost Impacts Among Plants of Different Sizes: Alternative III Requirements	9-33
9-22	Selected Statistics for Petroleum Dry Cleaning Model Plants: Number, Throughput, and Revenues, 1981. . .	9-36
9-23	Model Plant Internal Cash Flows.	9-37
9-24	Financial Feasibility Indicators for Small Commercial Plants	9-38
9-25	Financial Feasibility Indicators for Medium Commercial Plants	9-39
9-26	Financial Feasiblity Indicators for Large Commercial Plants	9-40
9-27	Financial Feasibility Indicators for Small Industrial Plants	9-41
9-28	Financial Feasiblity Indicators for Large Industrial Plants	9-42
9-29	Financial Feasibility Indicators for a Breakeven Level Commercial Plant: Annual Dry Cleaning Throughput of 59,940 Kilograms (138,170 pounds). . .	9-48
9-30	Financial Feasibility Indicators for a Breakeven Level Industry Plant: Annual Dry Cleaning Throughput of 59,940 Kilograms (138,170 pounds). . .	9-49
9-31	Annualized Costs and Cumulative Capital Requirements Compared to the Baseline, Fifth Year After Proposal of NSPS	9-57

LIST OF TABLES (continued)

Table		Page
B-1	Index to Environmental Impact Considerations	B-2
C-1	Dryer Emissions Data, Plant A	C-3
C-2	Recovery Dryer Data Compilation, Plant B	C-6
C-3	Recovery Dryer Data Compilation, Plant C	C-14
C-4	Total Solvent Emissions Due to Disposal of 14 Filter Cartridges (12 Carbon-Core and 2 All-Carbon) as a Function of Drainage Time.	C-21
C-5	Record of Still Waste Boildown Samples	C-24
C-6	Summary of Dry Cleaning Carbon Adsorption Optimization Program Operating Data, Plant E.	C-29
C-7	Comparison of Oil, Still Waste, and Solvent, Plant F.	C-34
D-1	Model Plant Emission Rates for Modified Regulatory Alternative III	D-3
D-2	Annual VOC Emission Impacts of Modified Regulatory Alternative III in the Five Model Plants	D-5
D-3	Projected Number of Affected Plants Over Ten Years Following Proposal of the Standards	D-6
D-4	Cumulative Nationwide VOC Emissions and Nationwide VOC Emission Reductions of the Five Model Plant Categories Under Modified Regulatory Alternative III for Ten Years	D-8
D-5	Annual Water Pollution Impacts of Emission Control in Five Model Plants	D-10
D-6	Cumulative Nationwide Water Impacts of Emission Control in Model Plants Under Modified Regulatory Alternative III for Ten Years	D-12
D-7	Annual Energy Impacts of Two Regulatory Alternatives in Five Model Plants	D-13
D-8	Cumulative Nationwide Energy Impacts in Five Model Plant Categories Under Modified Regulatory Alternative III for Ten Years	D-15
D-9	Reduction in Volume of Petroleum Solvent Consumed in the Three Impacted Model Plants	D-16

LIST OF TABLES (concluded)

Table		Page
D-10	Capital and Annualized Costs of Controls in a Large Commercial Model Plant	D-18
D-11	Capital and Annualized Costs of Controls in a Small Industrial Model Plant	D-19
D-12	Capital and Annualized Costs of Control in a Large Industrial Model Plant	D-20
D-13	Summary of the Annualized Cost Difference from Baseline, Emission Reduction, and Cost Effectiveness of Control Alternatives in Model Plants	D-21
D-14	Nationwide Cost Analysis of Regulatory Alternatives in the Three Impacted Model Plant Categories Projected for Five Years After Proposal	D-23
D-15	Nationwide Cost Analysis of Regulatory Alternatives in the Three Impacted Model Plant Categories Projected for Ten Years After Proposal	D-24

1. SUMMARY

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended in 1977. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which ". . .causes or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare." This background information document supports the proposed standards, which would control volatile organic compound (VOC) emissions from petroleum solvent dry cleaning facilities.

The dry cleaning industry is a service industry involved in the cleaning and/or renting of apparel. Petroleum solvent dry cleaning is offered by the commercial and industrial sectors of the industry and represents about 30 percent of the total quantity of apparel cleaned by the aggregate dry cleaning industry.

1.1 REGULATORY ALTERNATIVES

In order to evaluate the environmental, economic, and energy impacts associated with implementation of standards for the petroleum solvent dry cleaning industry, the Administrator has examined several regulatory alternatives for petroleum solvent dry cleaning. The three regulatory alternatives developed for controlling VOC emissions are summarized below.

- Regulatory Alternative I – No new source performance standards (NSPS) would be promulgated for the petroleum solvent dry cleaning industry. For the purpose of determining impacts, this alternative uses baseline emission control levels to project VOC emission growth.

- Regulatory Alternative II - All affected petroleum dry cleaning facilities would be required to reduce VOC emissions by means of a maintenance program which would eliminate perceptable fugitive leaks, and would minimize cartridge filter emissions
- Regulatory Alternative III - All affected petroleum dry cleaning facilities would be required to select solvent recovery dryers when purchasing new dryers and to comply with the provisions of Regulatory Alternative II.

1.2 ENVIRONMENTAL IMPACT

The environmental and energy impacts of the regulatory alternatives are summarized in Table 1-1. Regulatory Alternative I has the greatest adverse environmental impact while Alternative III has the greatest beneficial impact. The maximum nationwide VOC emission reduction occurs under Regulatory Alternative III, with negligible water pollution and solid waste impacts. Regulatory Alternative III also produces the most favorable energy impacts due to the significantly lower energy consumption rates of the recovery dryers relative to the standard dryer. The environmental and energy impacts are discussed in detail in Chapter 7.

1.3 ECONOMIC IMPACT

The estimated economic impacts are also summarized in Table 1-1. The Regulatory Alternative II economic impact is unquantifiable and is, therefore, assumed to be negligible. Regulatory Alternative III produces beneficial economic impacts for petroleum solvent dry cleaning facilities having large throughput capacities. The economic impacts are discussed in detail in Chapter 8.

Table 1-1. ASSESSMENT OF ENVIRONMENTAL, ENERGY, AND ECONOMIC IMPACTS FOR EACH REGULATORY ALTERNATIVE CONSIDERED FOR PETROLEUM SOLVENT DRY CLEANING PLANTS

Administrative alternative	Air impact	Water impact	Solid waste impact	Energy impact	Economic impact
Regulatory Alternative I	-3**	0	-1**	-2**	0**
Regulatory Alternative II	+1**	0	+1**	-1**	+1**
Regulatory Alternative III	+3**	-1**	+1**	+2**	+2**

^{a}KEY:

+	Beneficial impact	2	Small impact	*	Short term impact
-	Adverse impact	3	Moderate impact	**	Long term impact
0	No impact	4	Large impact	***	Irreversible impact
1	Negligible impact	5	Very large impact		

2. INTRODUCTION

2.1 BACKGROUND AND AUTHORITY FOR STANDARDS

Before standards of performance are proposed as a Federal regulation, the air pollution control methods available to the affected industry are identified. The economic, environmental and energy impacts associated with each of the available control methods are also identified. Control levels that correspond to the control efficiencies of the available technologies are expressed as regulatory alternatives. Each of these alternatives is evaluated by EPA as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the economics and well-being of the industry, the impacts on the national economy, and the impacts on the environment. This document presents the information obtained in these investigations to allow interested persons the opportunity to inspect the information considered by EPA in the development of the proposed standards.

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411) as amended, hereinafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which "causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger the public health or welfare."

The Act requires that standards of performance for stationary sources reflect ". . .the degree of emission reduction achievable which (taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated for that category of sources." The standards apply only to stationary sources whose construction or modification commences after regulations are proposed by publication in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions that apply to the process of establishing standards of performance.

1. EPA is required to list the categories of major stationary sources that have not already been listed and regulated under standards of performance. Regulations must be promulgated for these new categories on the following schedule:

- 25 percent of the listed categories by August 7, 1980.
- 75 percent of the listed categories by August 7, 1981.
- 100 percent of the listed categories by August 7, 1982.

A governor of a State may apply to the Administrator to add a category not on the list or may apply to the Administrator to have a standard of performance revised.

2. EPA is required to review the standards of performance every 4 years and, if appropriate, revise them.

3. EPA is authorized to promulgate a standard based on design, equipment, work practice, or operational procedures when a standard based on emission levels is not feasible.

4. The term "standards of performance" is redefined, and a new term "technological system of continuous emission reduction" is defined. The new definitions clarify that the control system must be continuous and may include a low-polluting or non-polluting process or operation.

5. The time between the proposal and promulgation of a standard under Section 111 of the Act may be extended to 6 months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any non-air quality health and environmental impacts, and energy requirements.

Congress had several reasons for including these requirements. First, standards with a degree of uniformity are needed to avoid situations in which some States may attract industries by relaxing standards relative to other States. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more expensive retrofitting when pollution ceilings are reduced in the future. Fourth, certain types of standards for coal-burning sources can adversely affect the coal market by driving up the price of low-sulfur coal or effectively excluding certain coals from the reserve base because their untreated pollution potentials are high. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improved technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under Section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under Section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area that falls under the provisions for prevention of significant deterioration of air quality in Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas be subject to best available control technology. The term "best available control technology" (BACT), as defined in the Act, means:

> ". . .an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from, or which results from, any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall

> application of 'best available control technology' result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to Sections 111 or 112 of this Act." (Section 169(3)).

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases, physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases in which it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions (high concentrations for short periods during filling and low concentrations for longer periods during storage) and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, Section 111(j) authorizes the Administrator to grant waivers of compliance to permit a source to use innovative continuous emission control technology. To grant the waiver, the Administrator must find (1) a substantial likelihood that the technology will produce greater emission reductions than the standards require, or an equivalent reduction at lower economic, energy, or environmental cost, (2) the proposed system has not been adequately demonstrated, (3) the technology will not cause or contribute to an unreasonable risk to the public health, welfare, or safety, (4) the governor of the State where the source is located consents, and (5) the waiver will not prevent the attainment or maintenance of any ambient standard. A waiver may have conditions attached to ensure that the source will not prevent attainment of any NAAQS. Any such condition will have the force of a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to 3 years to meet the standards with a mandatory progress schedule.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Adminstrator to list categories of stationary sources which have not been listed before. The Administrator ". . .shall include a category of sources in such list if in his judgment it causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow while adhering to the schedule referred to earlier.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these "areas" are actually pollutants emitted by stationary sources. Source categories that emit these pollutants are evaluated and ranked by a process involving such factors as (1) the level of emission control (if any) already required by State regulations, (2) estimated levels of control that might be required from standards of performance for the source category, (3) projections of growth and replacement of existing facilities for the source category, and (4) the estimated incremental amount of air pollution that could be prevented in a pre-selected future year, by standards of performance for the source category. Sources for which new source performance standards were promulgated or were under development during 1977, or earlier, were selected on these criteria.

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all major source categories not yet listed by EPA. These are (1) the quantity of air pollutant emissions that each such category will emit or will be designed to emit, (2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare, and (3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases, it may not be feasible to immediately develop a standard for a source category with a high priority. This situation might occur when a program of research is needed to develop control techniques, or because techniques for sampling and measuring emissions may require refinement. In developing standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Furthermore, even late in the development process, the schedule for completion of a standard may change. For example, inability to obtain emission data from well-controlled sources in time to pursue the development process systematically may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution and emissions from some of these facilities may be insignificant or very expensive to control. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by a standard of performance, all pollutants or facilities within that source category might not be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must (1) realistically reflect best demonstrated control practice, (2) adequately consider the cost, the non-air quality health and environmental impacts, and the energy requirements of such control, (3) be applicable to existing sources that are modified or reconstructed as well as to new installations, and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for developing standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated. The standard-setting process involves three principal phases of activity: (1) information gathering, (2) analysis of the information, and (3) development of the standard of performance.

During the information-gathering phase, industries are queried through a telephone survey, letters of inquiry, and plant visits by EPA representatives. Information is also gathered in other ways, including literature searches. From the knowledge acquired about the industry, EPA selects certain plants at which emission tests are conducted to provide reliable data that characterize the pollutant emissions from well-controlled existing facilities.

In the second phase of a project, the information gathered about the industry and the pollutants emitted is used to analyze potential control strategies. Hypothetical "model plants" are defined to provide a common basis for the analysis. The model plant parameters, national pollutant emission data, existing State regulations governing emissions from the source category and available control methods are then used in establishing "regulatory alternatives." These regulatory alternatives represent the different levels of emission control available.

EPA evaluates the impact of each regulatory alternative on the economics of the industry and the nation, on the environment, and on energy consumption. Based on the evaluation, EPA selects the best regulatory alternative as the basis for the standards of performance.

In the third phase of a project, the selected regulatory alternative is used to develop the actual standards of performance. This development process provides for review of the developing regulation by interested parties. EPA solicits comments from members of the National Air Pollution Control Techniques Advisory Committee, industry representatives and any other interested individuals or groups.

After completion of the proposed standards, the regulation and supporting rationale are published in the Federal Register with a request for public comment. EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standard with interested parties. All comments from the public are evaluated, and the standards of performance may be altered in response to the comments. The final regulation is then signed by the Administrator and published along with supporting rationale in the Federal Register.

2.4 CONSIDERATION OF COSTS

Section 317 of the Act requires an economic impact assessment with respect to any standard of performance established under Section 111 of the Act. The assessment is required to contain an analysis of (1) the costs of compliance with the regulation, including the extent to which the cost of compliance varies depending on the effective date of the regulation and the development of less expensive or more efficient methods of compliance, (2) the potential inflationary or recessionary effects of the regulation, (3) the effects the regulation might have on small business with respect to competition, (4) the effects of the regulation on consumer costs, and (5) the effects of the regulation on energy use. Section 317 also requires that the economic impact assessment be as extensive as practicable, taking into account the time and resources available to EPA.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and in terms of the control costs that would be incurred as a result of compliance with typical, existing State control regulations. An incremental approach is necessary because both new and existing plants would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the economic impact upon the industry resulting from the cost differential that would exist between a proposed standard of performance and the typical State standard.

Control of air pollutant emissions may cause water pollution and solid waste disposal problems. The total environmental impact of an emission source must, therefore, be analyzed and the associated costs assessed.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to provide an accurate estimate of potentially adverse economic impacts. It is also essential to identify the capital requirements for pollution control systems already placed on plants so that the additional capital requirements necessitated by these Federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to finance the additional control equipment requipments of the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires Federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performance for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by the Agency for proposed actions under Section 111 of the Clean Air Act. Essentially, the Court of Appeals has determined that the best system of emission reduction requires the Administrator to take into account counter-productive environmental effects of a proposed standard, as well as economic costs to the industry. On this basis, therefore, the Court established a narrow exemption from NEPA for EPA determination under Section 111.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to Section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969." (15 U.S.C. 793(c)(1))

Nevertheless, the Agency has concluded that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by Section 102(2)(C) of NEPA, EPA has adopted a policy requiring that environmental impact statements be prepared for various regulatory actions, including standards of performance developed under Section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section in this document is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are identified and discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as ". . .any stationary source, the construction or modification of which is commenced. . ." after the proposed standards are published in the Federal Register. An existing source is redefined as a new source if "modified" or "reconstructed" as defined in amendments to the general provisions of Subpart A of 40 CFR Part 60, which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Any physical or operational change to an existing facility which results in an increase in the emission rate of any pollutant for which a standard applies is considered a modification. Reconstruction, on the other hand, means the replacement of components of an existing facility to the extent that the fixed capital cost exceeds 50 percent of the cost of constructing a comparable entirely new source and that it be technically and economically feasible to meet the applicable standards. In such cases, reconstruction is equivalent to a new construction.

Promulgation of a standard of performance requires States to establish standards of performance for existing sources in the same industry under Section 111(d) of the Act, if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under Section 108 or which has not been listed as a hazardous pollutant under Section 112). If a State does not act, EPA must establish such standards. General provisions outlining procedures for control of existing sources under Section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, Section 111 of the Act provides that the Administrator ". . .shall, at least every 4 years, review and, if appropriate, revise. . ." the standards. Revisions are made to ensure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3. PETROLEUM DRY CLEANING INDUSTRY

This section describes the domestic petroleum solvent dry cleaning industry. The basic dry cleaning process itself along with specific parameters including solvent characteristics, emissions, and the major petroleum dry cleaning equipment is discussed.

3.1 INDUSTRY DESCRIPTION

The dry cleaning industry is a service industry involved in the cleaning and/or renting of apparel. The total industry is subdivided according to the type of solvent used and the type of services offered. The solvents used are categorized into three broad groups: petroleum, perchloroethylene (perc), and trichlorotrifluoroethane (F113, a registered trademark) solvents. The industry also is composed of three sectors which are delineated by the type of services offered. These are: (1) the self-service or coin-operated sector, (2) the commercial dry cleaning sector, and (3) the industrial dry cleaning sector. This report is concerned only with the sectors that use petroleum dry cleaning solvents.

Petroleum dry cleaning represents about 30 percent of the total quantity of clothes cleaned by the dry cleaning industry. Petroleum dry cleaning services are offered only by the commercial and industrial sectors of the industry, and represent about 25 and 30 percent, respectively, of the total clothes throughput for each of these industry sectors (Fisher, 1980b; Sluizer, 1981). Coin-operated or self-service petroleum dry cleaning plants are prohibited by National Fire Protection Codes due to the highly volatile and flammable nature of petroleum solvents (NFPA, 1979). Consequently, most commercial and industrial petroleum dry cleaning plants are located away from densely populated residential areas and shopping centers.

Commercial petroleum dry cleaning plants offer dry cleaning services to the general public, and include both independently owned ("Mom and Pop") dry cleaners and franchised ("One Hour Dry Cleaning") companies. Typically, these plants clean personal items such as suits, coats, and dresses. In the franchised facilities, a central cleaning plant may support one or more pickup and distribution outlets. Of the 25,000 domestic commercial cleaners, approximately 6,000 (representing 25 percent of the dry cleaning industry throughput as of 1979) use petroleum solvents (Fisher, 1980b). The average throughput in a typical commercial plant is 25 megagrams of cleaned articles per year.

Industrial dry cleaning plants are much larger than their commercial counterparts and cater to industrial, professional, and institutional customers. Articles such as work uniforms, mats, mops, and rugs generally are cleaned by industrial dry cleaners, often in conjunction with rental operations. There are approximately 1,000 industrial cleaning plants nationwide. In 1979 approximately 230 of these industrial plants used petroleum solvent in some portion of their cleaning operation (Sluizer, 1981). A typical industrial petroleum dry cleaning plant processes roughly 515 megagrams of articles each year. Thus, the combined industrial and commercial petroleum dry cleaning sectors process approximately 250,000 megagrams of articles each year.

3.2 PROCESS DESCRIPTION

Petroleum dry cleaning operations are similar to detergent and water wash operations. Unlike perchloroethylene dry cleaning, which can have both washing and drying operations in the same machine (dry-to-dry), petroleum dry cleaning is a batch operation in which articles are washed and dried in separate machines. Figure 3-1 depicts a typical petroleum dry cleaning operation. Articles to be dry cleaned are sorted into lots according to color, fabric, degree of soiling, etc., and are placed in their appropriate washers. For example, one lot might consist of light colored, light weave, casual clothing which are placed in one washer, while another lot might be made up of heavy weave, heavily soiled industrial uniforms placed in another washer. Articles are then agitated in the solvent, with total washing cycle times ranging from 20 to 40 minutes,

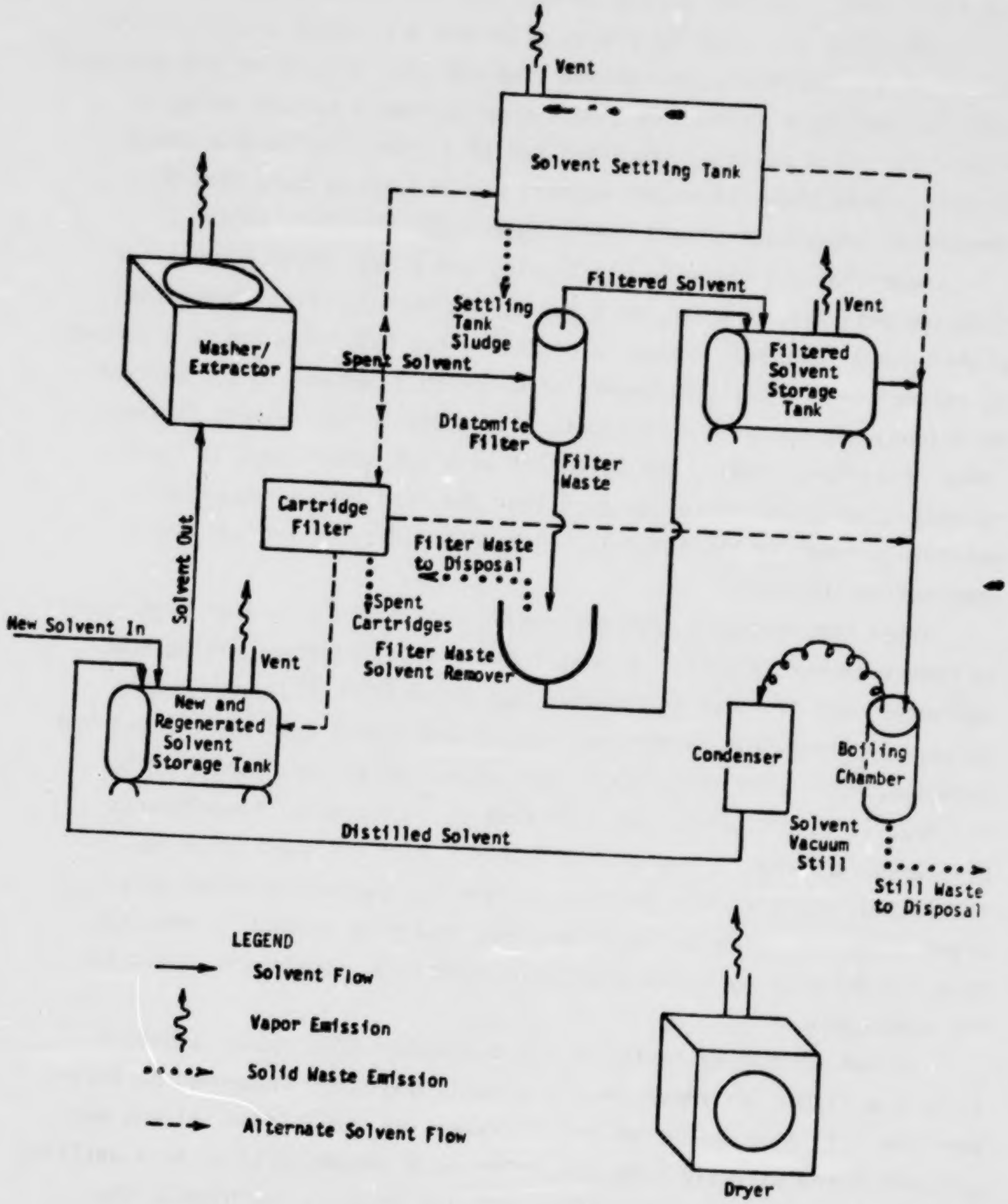


Figure 3-1. Petroleum Dry Cleaning Plant Flow Diagram.

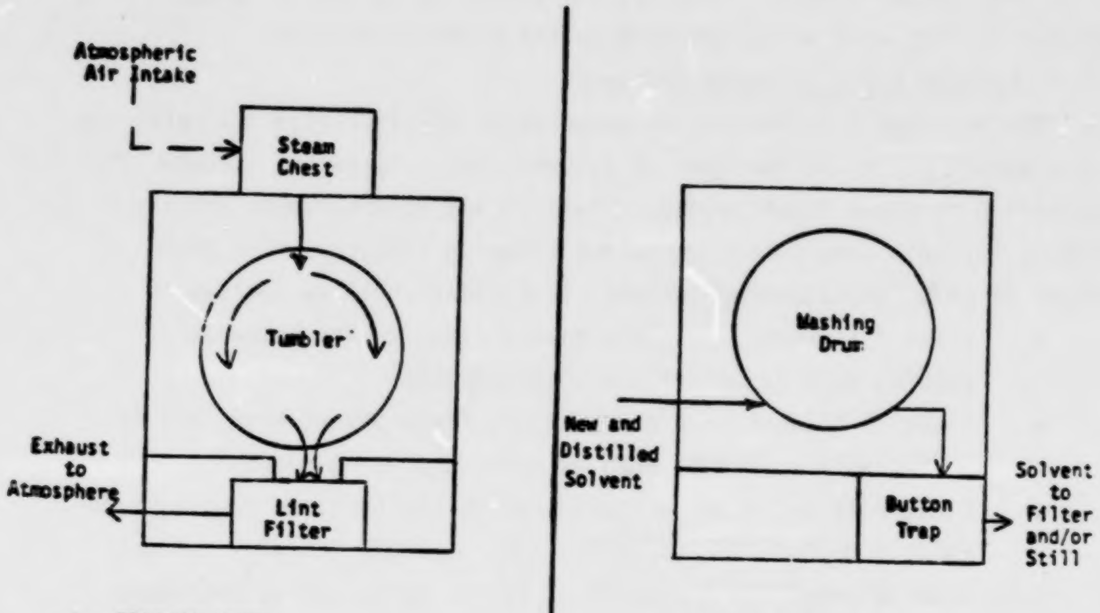
depending on the load size, fabric, and soil loading (Washex, 1974). The more heavily soiled articles go through two or more wash cycles: the first with recycled, soiled solvent and the second with clean solvent.

Industrial dry cleaning plants often use a cleaning process where water-soluble materials are removed from articles in a water and detergent wash followed by a solvent wash operation to remove solvent soluble materials. This process, sometimes called a "dual" or "double phase" process, takes place in modern washers and is used by more than 90 percent of industrial plants (see Figure 3-2B) (Sluizer, 1981).

Commercial dry cleaning plants also use a dual phase process for cleaning articles; however, most (up to 90 percent) of the commercial plants use a "charged" system, a process where both soap (up to 4 percent by volume) and controlled amounts of water (0.1 percent to 0.3 percent by volume) are manually or automatically added to the solvent (Fisher, 1980b; Phillips, 1966). The volume of soap and water added to the solvent usually is controlled by either the load type, load weight, moisture present in the solvent, relative humidity of the air, or a combination thereof.

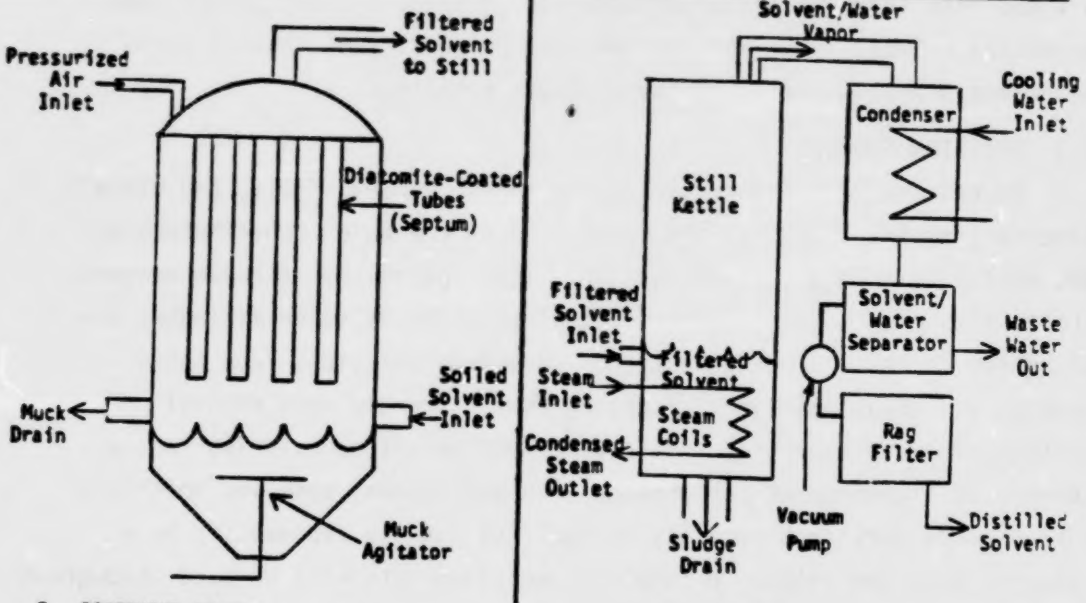
After completion of the wash cycle, articles are spun at high speed to remove excess solvent. This spin cycle usually occurs in the same equipment used for washing; however, as noted in a 1975 dry cleaning survey, approximately 23 percent of existing plants (the older ones) had separate, high speed centrifugal extractors (Watts and Fisher, 1975). In 1980, it is estimated that a minimum of 3 percent of these plants have been converted to washer/extractors. When the spin cycle has terminated, articles are transferred from the washer/extractor to a dryer (tumbler). Inside the dryer, any remaining solvent is removed from the articles by evaporation in a heated air stream and vented to the atmosphere.

Soiled solvent extracted during the washer spin cycle is passed through a filter to remove insoluble soils and other suspended particles. When the soil load in the solvent is excessive, soil-laden solvent may be transferred directly from the washer to a vacuum still or to a settling tank prior to distillation. After settling (usually overnight), the heavy oils, dirt, and grease are decanted, and the solvent is sent to a vacuum still where it is purified. When oil and grease loading is low,



a. STANDARD DRYER

b. WASHER/EXTRACTOR



c. DIATOMITE FILTER

d. VACUUM STILL

Figure 3-2. Typical Dry Cleaning Equipment in Existing Plants.

distillation is often bypassed and filtration serves as the only means of solvent replenishment. Finally, the distilled solvent is pumped into another holding tank or is returned to the washer/extractor.

3.2.1 Petroleum Dry Cleaning Solvents

The National Fire Protection Association (NFPA) classifies petroleum dry cleaning plants by the type of solvent used. Solvents, in turn, are classified by their flash points. Class II and IIIA solvents are the primary solvents used in the petroleum cleaning industry. The NFPA number 32-1979, dry cleaning solvent classification is as follows:

- Class I Solvents - Liquids having flash points below 38°C (100°F) such as 50°F flash point naphtha.
- Class II Solvents - Liquids having flash points from 38°C to 59°C (100°F to 139°F) such as quick drying solvents.
- Class IIIA Solvents - Liquids having flash points ranging from 60°C to 93°C (140°F to 199°F) such as 140°F "safety" solvent.

Petroleum solvents are a mixture of mainly C_8 to C_{12} hydrocarbons that are similar to kerosene. These hydrocarbons can be further subdivided into three molecular structures: aliphatics, alicyclics, and aromatics. Table 3-1 gives the chemical properties of several types of petroleum solvents including their aromatic contents.

3.3 EMISSION SOURCES

Dryers, solvent filters, settling tanks, vacuum stills, and miscellaneous (fugitive) sources are identified as the major contributors of VOC emissions in a dry cleaning plant. The operations of these sources, their emissions, and the development of baseline emission estimates are discussed in the following sections. Baseline emissions from these sources are those emissions resulting from currently used control technologies and represent the level of VOC emissions existing in the absence of standards of performance. In most cases, baseline emissions for a source vary from facility to facility and are represented by a range of emission rates. A "nominal" emission rate will be used throughout this document to represent the range of emission estimates for a source. The nominal rates are based on a combination of the following: actual test data, emissions data from industry officials, or emissions estimates acknowledged as being representative of a typical range of emissions.

Table 3-1. PHYSICAL AND CHEMICAL PROPERTIES OF HYDROCARBON DRY CLEANING SOLVENTS

Trade Name	Producer	Boiling Range, °F			Flash Point °F T.C.C.	Vapor Pressure mm Hg at 20°F	L.E.L.	Ave. Mol. wt.	Pounds per Gallon at 60°F	Aniline Point °F	Kauri Butanol Value	Composition, Vol. %				
		Initial	50%	Dry Point								Paraffins	Naphthenes	Aromatics		Olefins
														C_8+	Total	
Skellysolve S-66	Getty	305	329	385	104	3.2	1.1	142	6.48	142	36	43.4	49.4	6.8	6.8	0.4
Varsol 3	Exxon	310	327	348	105	10.0			6.46	130	38			19.0	19.0	
325	Chevron	320	335	368	105	5.0	1.0	138	6.57	145.2	36	35.4	62.2			
AMSCO Napthol MS*	Union	313	323	353	106	3.0	1.0	138	6.32	160	31	64	35		1	
Varsol 1	Exxon	313	346	390	106	10			6.56	130	37			18	18	
Skellysolve "S-2"	Getty	314	321	331	102	3.1	1.1		6.47	133	37	39.5	48.2	11.7	11.7	0.6
Kwik-Dri**	Ashland	315	330	355	105	<10	1	128	6.46	154	32	57	41	2	2	0.3
Mineral Spirits	Ashland	315	344	385	105	<10	1	145	6.55	140	36	54	36	9.5	9.5	0.3
Mineral Spirits 66/3	Ashland	315	342	385	105	<10	1	145	6.55	155	31	57	41	2	2	0.2
Varsol 18	Exxon	315	344	395	110	10			6.42	130	32			7.6	7.8	
AMSCO Mineral Spirits 66/3	Union	315	345	375	104	1.1	.7		6.55	153	33	61	37	2.0	2.0	
Sol 340	Shell (EOR)	316	324	347	104	2.8	1.0		6.37	150	33	47.2	50.2	2.6	2.6	
Mineral Spirits 145-EC	Shell (EOR)	317	336	388	112	2.7	1.0		6.49	145	34	47.5	45.1	7.4	7.4	
AMSCO Odorless MS	Union	354	362	386	128	<1.0			6.33	184	27	86	14			
Odorless MS	Ashland	355	365	395	128	<10	1		6.33	185	28	87	13			
140 Solvent	Ashland	362	375	390	140	<10	1		6.54	160	31	60	37	3.0	3.0	0.3
Skellysolve "T"	Getty	363	375	400	143	0.7	1.1		6.57	151	32	35.3	54.5	9.3	9.3	0.9
AMSCO 140 Solvent 66/3	Union	368	383	402	146	<1.0	1.0		6.51	164	30	55	44	1.0	1.0	
Sol 140	Shell (EOR)	371	380	416	143	<1.0			6.56	153	31	54.9	39.2	5.9	5.9	
Chevron Thinner 410B	Chevron	370	383	406	142		0.9	157	6.78	147.4	35.8	36.6	60.6			

*Used during Rhode Island test.

**Used during Lakeland test.

[a] Source: Personal Communications and the "Raw Materials Index, Solvents," National Paint and Coating Association, Washington, D.C.; and Chevron Research Company

3.3.1 Dryers

Standard (non-recovery) petroleum solvent dryers remove liquid solvent from drying articles by forcing ambient air over steam heated coils where it is heated and then directing the heated air stream through the drying articles in the dryer tumbler and out through the lint filter to the atmospheric exhaust (see Figure 3-2A). Typically, these units are manufactured in three discrete capacities of 22, 45, and 180 kilograms (50, 100, and 400 pounds) with at least two operating cycles (door-open and drying) and frequently a third cool-down cycle.

The standard dryer is loaded (and unloaded) in the door-open cycle. During this operation, solvent-laden articles are loaded into the perforated tumbler basket, with the exhaust blower operating in order to remove solvent vapors from the loading area and the flow of steam to the air stream heating coils stopped by a solenoid valve. Thus, in the door-open cycle, ambient air from the dryer door area is drawn into the dryer through the dryer door and exhausted to the atmosphere. The flow rate of this vapor stream is approximately the maximum rated flow rate for the individual dryer, ranging from 28 m^3/min (1,000 ft^3/min) for a 22 kilogram dryer to 340 m^3/min (12,000 ft^3/min) for a 180 kilogram unit (Marvel et al., 1980). Typically, loading and unloading durations vary between 1 and 5 minutes, depending on the levels of automation and operator efficiency.

The drying cycle begins when the dryer door is closed and the drying cycle timer is activated. The tumbler basket rotates, a solenoid valve in the steam chest supply permits steam to enter the heating coils, and the blower pulls ambient air into the tumbler through the steam coils where the air is heated to about 100°C (212°F). In the tumbler, the heated air forces solvent and water to evaporate from the tumbling articles at an optimum drying temperature range of 60°C to 66°C (140°F to 150°F) as measured at the dryer lint filter (Marvel et al, 1980). Because the evaporation process absorbs heat at a relatively constant temperature, the actual temperature of the drying articles is a function of their liquid (solvent and water) content and gradually increases during the drying cycle. Upon leaving the tumbler basket, the solvent-laden vapor stream passes through a bag-type lint filter, through the exhaust blower, and finally is exhausted to the atmosphere at flow rates ranging from 20 m^3/min (750 ft^3/min) in a 22 kilogram dryer to 250 m^3/min (9,000 ft^3/min) for a 180 kilogram unit (Jernigan and Lutz, 1980; Lutz et al, 1980). Typically, the duration of the drying cycle ranges from 15 to 50 minutes, with short durations reflecting smaller loads of heat-sensitive fabrics containing little solvent (silks) and longer drying cycle times indicating larger loads of heavy fabric (wools) containing large quantities of solvent (IFI, 1973).

Certain manufacturers of standard dryers build units having a second timer-controlled cycle following the drying cycle. During this cool-down cycle, the steam solenoid valve is closed and the tumbling articles are exposed to a continuous stream of ambient temperature air which permits cooling of the dried articles while preventing excessive wrinkling which can occur when hot articles are removed from the dryer. With typical durations of 2 to 5 minutes, the cool-down cycle allows the tumbling load to cool to ambient temperature while venting additional solvent (and water) vapor to the atmosphere at flow rates identical to those of the drying cycle.

VOC emissions associated with the drying of articles washed in petroleum solvent can occur during all three of the previously discussed standard dryer operating cycles. During the door-open cycle, solvent evaporated from the articles being loaded or unloaded contributes to the overall level of fugitive VOC emissions in the plant. These emissions in the vicinity of the dryer door are drawn into the dryer by the exhaust blower and are vented to the atmosphere through the dryer exhaust. Although articles removed from the dryer are assumed to be dry (solvent-free), EPA tests have indicated that the solvent content of dried articles may be significant, but cannot be accurately measured due to the tendency of dried articles to accumulate atmospheric water (Jernigan and Lutz, 1980).

Drying cycle VOC emissions occur when liquid solvent and water are evaporated from the tumbling articles and exhausted to the atmosphere. The principal determinant of the extent of these emissions is the solvent content of the drying articles, which is determined by the type of fabric, the extraction efficiency of the washer, and the weight of articles being dried. During the drying cycle, the quantity of solvent and water emitted to the atmosphere is determined by the temperature and flow rate of the air stream within the dryer. The duration of the drying cycle also effects the dryer exhaust VOC emissions, but longer drying durations significantly increase exhaust emissions only when the drying temperature and air stream flow rate are sufficient to promote the evaporation of additional solvent from the tumbling clothes. Thus, the rate and total quantity of solvent evaporated from drying clothes is a function of the quantity of solvent available, the drying temperature and air flow rate, and the duration of the drying cycle.

In dryers with a cool-down cycle, VOC emissins from the dryer atmospheric exhaust are produced when unheated atmospheric air is blown across the tumbling articles. Because the temperature of the vapor stream is much lower than that of the drying cycle, it is assumed that very little additional solvent is evaporated during this cycle.

In an EPA demonstration test of an add-on carbon adsorber at a large industrial petroleum dry cleaning plant, a 180 kg (400 lb) standard dryer loaded with 115 kg (250 lbs) of work uniforms, shop towels, and fender covers had test average exhaust emissions of 14 kg VOC per 100 kg dry weight of articles cleaned (Lutz et al., 1980). An average of approximately 28 kg VOC per 100 kg dry weight of articles cleaned was emitted during an EPA test of a 50 kg (100 lb) standard dryer at another large industrial petroleum dry cleaning plant (Jernigan and Lutz, 1980). This dryer was loaded to 10 percent over-capacity with leather and cotton work gloves, exclusively. A study by a dry cleaning trade association indicated that petroleum solvent dryers emit an average of approximately 14 kg VOC per 100 kg dry weight of general apparel cleaned (Fisher, 1975). Thus, the overall average emission rate from a dryer based on these three data sources is 18 kg VOC per 100 kg dry weight of articles cleaned with a range of 14 kg to 28 kg for dryer VOC exhaust emissions.

3.3.2 Solvent Filters

Filtration in dry cleaning operations is a process used to remove most insoluble (dirt and lint) contaminants and, to a lesser extent, certain water-soluble contaminants (perspiration and food stains) from dry cleaning solvents. This is accomplished by rapidly passing large volumes of solvent through a porous medium that traps and simultaneously removes contaminants suspended in the solvent. Although diatomaceous earth filtration has been used traditionally in the industry, cartridge filtration is becoming the predominant form of solvent filtration (Fisher, 1980a).

3.3.2.1 Diatomite Filters. Diatomaceous earth (diatomite) filtration systems are composed of two parts: the filter medium and the structure that holds the filter medium, known as the septum (see Figure 3-2C). The filter medium, diatomaceous earth (diatomite) mixed with activated carbon, is used to remove insoluble contaminants by entrapping them in its porous surface. The septum is a rigid, porous surface (screen, cloth, or wire mesh) to which the filter medium adheres, thereby allowing pressurized solvent to flow through while simultaneously blocking the passage of particles. Filters are sized by the volume of solvent processed and range in size from 5,700 to 56,800 liters per hour (1,500 to 15,000 gallons per hour) (Washex, 1974).

During a wash cycle, articles are agitated in a bath of solvent. After the wash cycle, the soiled solvent is pumped to a filter for filtration. Filters vary, based on their mode of operation, septum type, and construction material. Single-charge filters (rigid tube or disc septums) have a single mass or "charge" of filter medium which is replaced after each wash load is completed. With multi-charge filters (bag, screen, and rigid tube septums) filter medium is added to the initial charge for each load of articles washed. Regenerative filters (flexible tube septums) have an initial mass of filter medium which is redistributed on the septum for each load of articles washed, without subsequent addition of filter medium. As of 1980, about 50 percent of the petroleum dry cleaning plants that utilize filtration used multi-charge diatomite filters, and the remaining 50 percent employed cartridge filters for solvent filtration (Fisher, 1980a). A trade association study has shown that initial masses of diatomite (precoats) average about 1 kg (2 lbs) per 3,800 liters (1,000 gal) of filter capacity, with diatomite being added during the operation at a rate of 0.5 kg (1 lb) per 45 kg (100 lbs) of articles cleaned (Leonhardt, 1966).

Filter medium is replaced when the pressure across the filter, due to the buildup of contaminants on the medium, reaches a predetermined level (up to 40 psi or 270 kilopascals). Spent filter medium (filter muck) is usually allowed to drain in the filter housing overnight or for 24 hours before it is discarded. An industry trade association determined that discarded filter medium that has been allowed to drain for 24 hours may contain from 5 to 10 kg solvent per 100 kg dry weight of articles cleaned for regenerative and multi-charge filters, respectively (NID, 1971). Thus, after a 24-hour drain time, an average of just under 8 kg of solvent per 100 kg dry weight of articles cleaned is retained in the discarded filter muck. This average can vary based on the soil loading and filter muck drainage procedure employed in individual plants. Also, devices such as centrifugal separators, and pressure or vacuum muck strippers have been used by a few large petroleum dry cleaning plants to recover solvent from diatomite filter muck (Fisher, 1981). However, these devices are not widely distributed through the industry and there is little current data on their performance as an emission control technique.

3.3.2.2 Cartridge Filters. Cartridge filtration is a continuous, two-stage process of filtration in which soil-laden liquid is forced under pressure first through a paper filter to remove entrained solids and then through a layer or layers of activated carbon which selectively entrap molecules of impurities in their porous surface. The term "cartridge" is used to denote replaceable units or canisters containing filtration paper and carbon or only carbon. Currently, it is projected that most of the petroleum dry cleaning plants using solvent filtration will employ cartridge filtration (Fisher, 1980a).

Cartridge filtration, as applied to the petroleum solvent dry cleaning industry, is a process in which soil-laden solvent is pumped from a washer to a vessel containing filter cartridges (see Figure 3-3). This vessel normally has a removable, pressure-sealed lid or top and can contain from 2 to 36 cartridges. Soil-laden solvent is initially forced under pressure through dual-component cartridges that contain both filter paper and carbon. In this process, solid particles of lint and dirt are trapped in the paper. The included activated carbon serves

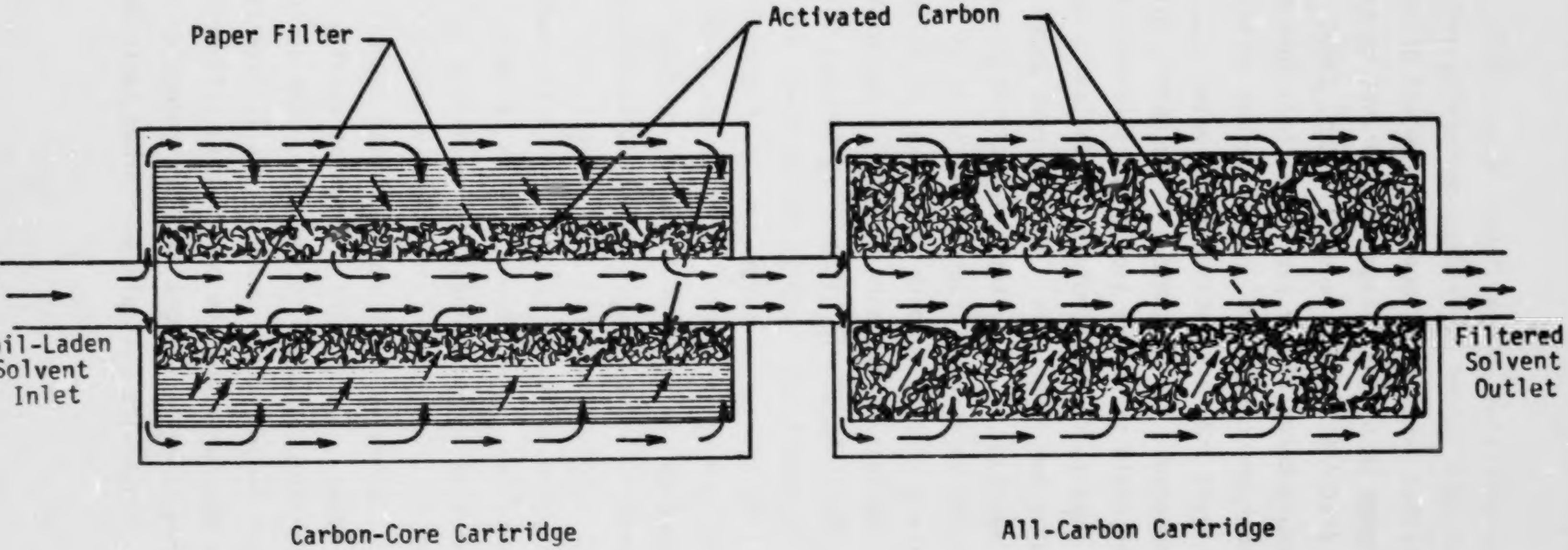


Figure 3-3. Cartridge Filtration System Schematic.

to remove soluble impurities such as fabric dyes. Next, the solvent is diverted to one or more filter cartridges containing only activated carbon. The activated carbon continues the removal of soluble impurities. After passing through this final stage, the solvent is transferred to storage to await distillation and reuse (Puritan, 1980).

Currently manufactured filter cartridges fall into two distinct categories: carbon-core cartridges and all-carbon cartridges. Carbon-core cartridges (see Figure 3-3) are encased in an outer metallic housing that is perforated around its circumference to permit solvent inflow. Beneath this outer rigid structure lies a circumferential layer of filtration paper that is folded accordian-style into a deeply-corrugated cylinder surrounding the inner core. This fibrous paper, similar to that found in an automotive oil filter, permits the pressurized solvent to flow inward to the core while trapping particles of dirt and lint along its extensive surface. Beneath this layer of filter paper lies the slotted metal surface of the core tube which contains granular activated carbon (Puritan, 1980). In passing through this material, the larger molecules of impurities, such as fabric dyes, are adsorbed by the carbon granules. The all-carbon cartridge (see Figure 3-3) continues the purification of the solvent which began at the carbon-core cartridge. Solvent flowing through the slots of the metal canister is forced through the enclosed activated carbon, resulting in additional removal of impurities and the outflow of a solid-free, purified solvent.

Although the process flow of carbon-core to all-carbon is typical of most cartridge filter installations, the containment, number, and physical arrangement of the cartridges varies widely as a function of the system's capacity. Cartridge filtration systems are "sized" by their manufacturer, based on the dry-weight load capacity of the existing washer (Puritan, 1980). The size of the system usually refers to the total number of filter cartridges it contains. The actual distribution of these cartridges ranges from a group of small, interconnected vessels containing one or two cartridges to one or more cylindrical tanks containing as many as 36 carbon-core cartridges that are connected to an additional vessel or vessels containing multiple all-carbon cartridges (Puritan, 1980).

The operation of a cartridge filtration system can be based on either the continuous (during washer operation) or batch (at predetermined intervals) processing of spent solvent. In continuous operations, the spent solvent in the washer is pumped through the filter and back to a filtered solvent tank. As this process continues on a day-to-day basis, the outer surfaces of the filter paper in each carbon-core cartridge become clogged with dirt and lint, while the carbon granules contained in both types of cartridges become coated with dyes and particles until they no longer purify the solvent stream. Dry cleaning trade association tests have shown that, under typical commercial conditions of soil-loading and throughput, the "life" of a filter cartridge is somewhere between 450 kg (1,000 lbs) and 500 kg (1,100 lbs) of articles washed (Bee and Fisher, 1976). Under conditions of heavy soil loading, however, the need for cartridge replacement is best indicated by the buildup of solvent pressure in the vessel due to the flow restriction caused by the clogged cartridges.

Atmospheric emissions from cartridge filters are limited to fugitive emissions that evolve from leaks and filter cartridge replacement, and evaporation of solvent contained in disposed cartridges. An EPA test of the amount of solvent contained in discarded filter cartridges was conducted at a medium commercial petroleum solvent dry cleaning plant that processes approximately 180 kg (400 lbs) of general apparel per day in a single 27 kg (60 lb) capacity washer (Plaisance, 1981). A 14-element cartridge filtration system was operated without cartridge replacement over a period of time when the plant had a throughput of approximately 8,600 kg (19,000 lbs.) of clothes washed. Results of this test indicated that draining the filter cartridges in their closed housing for at least 8 hours would result in an average solvent emission per cartridge of 1.6 kg (3.4 lbs). Based on an assumed cartridge life of 450 kg (1,000 lbs) of throughput, this would result in 0.35 kg of solvent being emitted per 100 kg of clothing throughput (Plaisance, 1981). Figure 3-4 illustrates the effect of drainage time on VOC emissions from discarded filter cartridges. The majority of the drainage takes place during the initial few minutes when liquid solvent is running freely from the canisters.

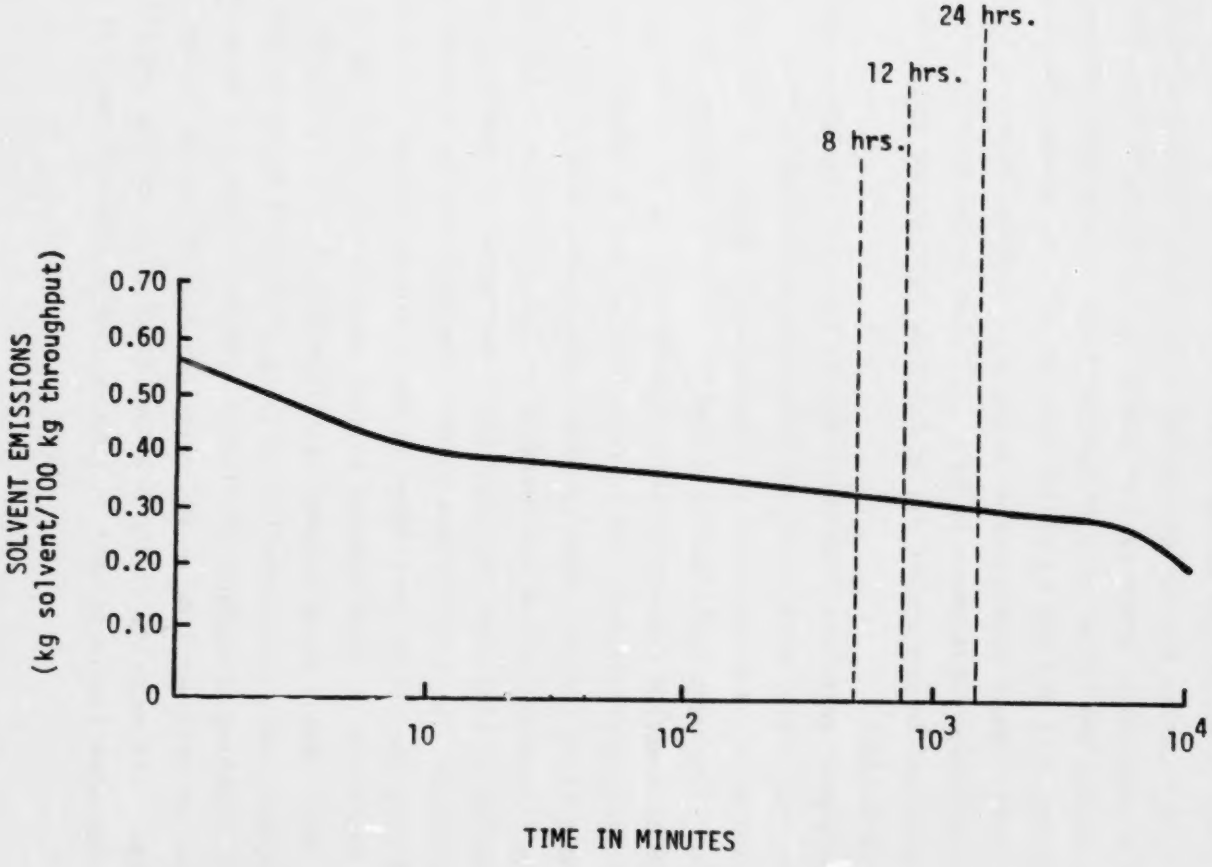


Figure 3-4. Solvent Emissions for Filter Cartridges as a Function of Drainage Time.

After 8 hours of drainage and evaporation, the cartridges have lost 37 percent of their undrained solvent content. After an additional 4 hours, they have lost only 3 percent more, indicating that extended drainage periods are unnecessary.

The value of cartridge VOC emissions obtained above, is in general agreement with a dry cleaning trade association estimate of 0.75 kg per 100 kg of articles cleaned (NID, 1971).

There is a current controversy in the dry cleaning industry concerning the cartridge filter's ability to eliminate the need for distillation. Although some plants have ceased their vacuum still operations after the installation of cartridge systems (Plaisance, 1981), both cartridge filter manufacturers (Puritan, 1980) and dry cleaning trade associations (Bee and Fisher, 1976) maintain that distillation is a necessary part of the process of solvent rejuvenation and is the only method for removing solvent-soluble impurities such as grease and oil. The installation of cartridge filtration equipment could, however, decrease the frequency of solvent distillation. This decrease would reduce not only filtration emissions, but also emissions associated with still wastes. Small plants with light soil loadings, in particular, could reduce their frequency of distillation by using cartridge filters to maintain the clarity of their solvent.

3.3.3 Settling Tanks

Settling tanks, as applied to the petroleum dry cleaning industry, are used to filter oils, grease and suspended particles from petroleum solvent. Settling tanks are utilized when other methods of filtration (cartridge filtration) are uneconomical due to heavy soil loadings in processed articles. The difference in densities of the solvent, oil, grease, and suspended particles forms the basis for the separation process. Petroleum solvent is less dense (0.7 to 0.8 kg/liter) than oils, grease, solids, and water and, therefore, rises to the top of the tank while the other materials settle to the bottom.

Settling tanks are conical bottom, cylindrical containers with two or more orifices for solvent flow and the venting of solvent vapors. These tanks vary in size, the maximum size being 5,680 liters (1,500 gal), with only two 5,680 liter tanks allowed per plant by national fire codes, totaling 11,360 liters (NFPA, 1979). Settling tanks operate in either batch or continuous modes. The batch operated settling tank (see Figure 3-5) is used where contaminated solvent is pumped from the washer and stored in the settling tank. The time allotted for settling depends upon the size and depth of the tank (tank capacity), the extent of solvent contamination, and the variation in densities of the contaminants in comparison to that of petroleum solvent. After allowing sufficient time for settling, a valve is manually opened at the base of the tank to drain off the residue. The residue, a very viscous liquid, is collected in a drum and allowed to set for a few hours to several days. Solvent is skimmed from the top of the residue at the end of this period, and the residue is then discarded, mixed with boiler fuel, or sold to a solvent reprocessor (Sluizer, 1981). The solvent remaining in the settling tank, after the removal of the residue is conveyed to the vacuum still for further purification.

The continuously operated settling tank, also known as a separator tank, (see Figure 3-6) has solvent flowing in and out on a continuous basis. Contaminated solvent from a washer is pumped to the settling tank. The solvent flows from the top of the tank as the heavy contaminants settle to the bottom. Periodically, residue is drained from these tanks and is discarded or utilized in the same manner as that from the batch operated tank.

There is no test data available on the solvent retention of settling tank waste. A vacuum still manufacturer stated, however, that approximately 2 Kg of solvent is lost with every kilogram of settling tank waste (Landon, 1981). An industrial trade association representative stated that the solvent content of settling tank waste can range from 80 to 200 percent by weight of the total waste (Sluizer, 1981).

The factors having a significant effect on the solvent retention of settling tank waste are not well known. Because settling tanks have no moving parts, the only factors that could increase the solvent content of the discarded waste are an insufficient settling time or excessive turbulence in the tank resulting from an excessive solvent flow rate. There is little that can be done to alleviate the latter problem of turbulance and an increase in the settling time should correct the former problem.

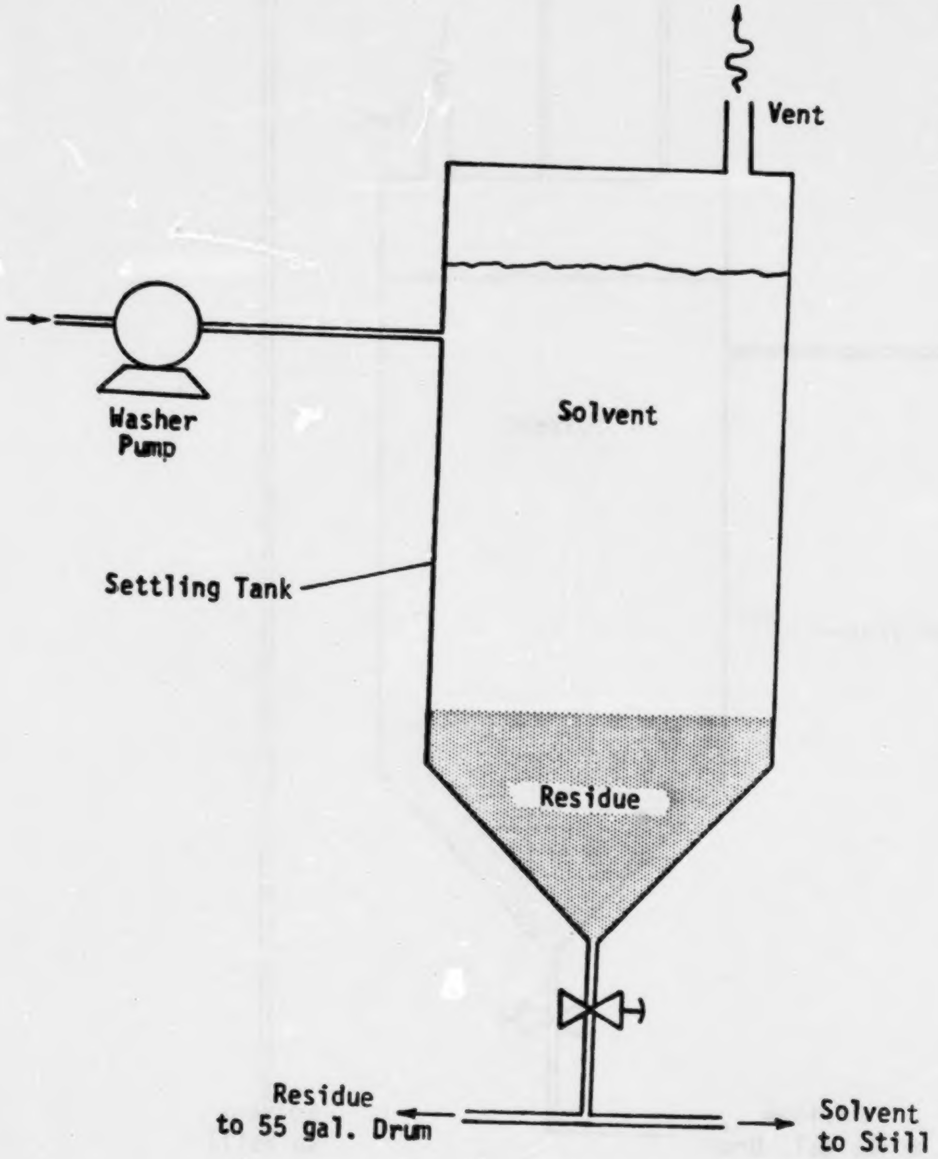


Figure 3-5. Batch Flow Settling Tank.

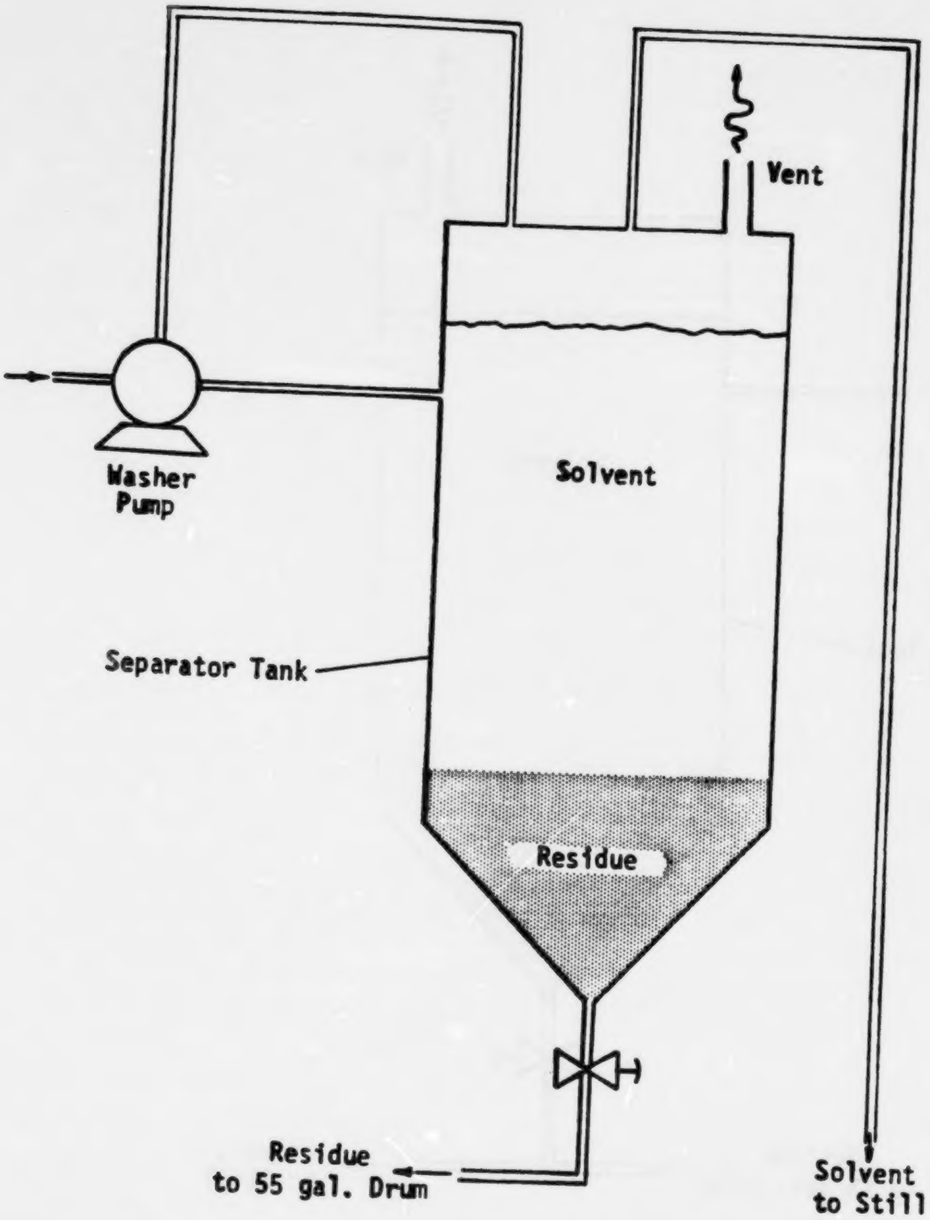


Figure 3-6. Continuous Flow Settling Tank.

The operation of a settling tank is dependent upon the mode of operation of the plant, the plant's capacity for storing the residue and the plant's settling tank and vacuum still capacities. Most dry cleaners use at least one of three approaches to remove their settling tank residue; burn it as a boiler fuel supplement, discard it with general dry cleaning waste or sell it to a solvent reprocessor. Trade association and industry representatives were unable to give any percentages of dry cleaners that use any of these three approaches, but one representative stated that the residue is usually too contaminated or viscous to distill in a dry cleaning vacuum still (Sluizer, 1981; Landon, 1981).

3.3.4 Vacuum Stills

The purpose of distillation in the petroleum dry cleaning industry is to separate liquids (primarily petroleum solvent) with lower boiling points from those with higher boiling points ("high boilers") such as oils, grease and solid residue (dirt, lint and detergents). The mixture of petroleum solvent, oils and grease that is conveyed to a still is typically a mixture of liquids with a wide range of boiling points. Additionally, there are significant differences in the boiling ranges of petroleum solvents themselves, as represented by the range of flashpoints from 38°C to 60°C (100 to 140°F). Consequently, a still should be operated at a temperature that will evolve (evaporate) the liquids that fall within the boiling range of petroleum solvents while leaving behind the oils, grease, and solid residue. Petroleum dry cleaning solvents have boiling ranges from 150°C to 215°C (300°F to 415°F) at atmospheric pressure. A steam pressure greater than 100 psi (670 KPa) is required to boil petroleum solvents under atmospheric conditions (Washex, 1973). Consequently, distillation of petroleum solvents takes place under a vacuum of 75 to 92 kPa (22 to 27 inches Hg) which lowers the boiling range for petroleum solvents to 107°C to 113°C (225°F to 235°F) at steam pressures of 235 to 600 kPa (35 to 90 psi). Vacuum stills are sized by the volume of solvent to be processed and range in size from 95 to 1,900 liters (25 to 500 gallons) per hour (Washex, 1973).

A vacuum still is composed of four principal parts: the boiling chamber, condenser, gravimetric seperator, and the moisture separator. Spent solvent from a washer, filter or settling tank is pumped to the boiling chamber of the vacuum still (see Figure 3-7). In the boiling chamber, steam-heated coils volatilize the solvent, leaving behind still residue (high boilers composed of oils, grease, and dirt). Solvent vapor and moisture pass from the boiling chamber into a water-cooled condenser where the vapors condense to a mixture of liquid solvent and water. This mixture is then piped to a gravimetric separator, where the solvent and water are separated by the differences in their densities. Finally, the solvent is pumped to the moisture separator, a tank containing cotton rags or salt pellets, where any remaining water is absorbed.

When the concentration of high boilers has reached a specified level, the liquid contained in the boiling chamber is allowed to boil for a period of up to 30 minutes in a process commonly called "boildown" in which most of the remaining solvent is removed. The need for boildown is indicated by visual inspection of solvent flow in a sight glass between the condenser and separator (indicating that the evolution and condensation of solvent vapors is seriously impeded or halted). During boildown the solvent flow to the still is manually shut off and steam flow is increased to the maximum available level by opening a valve in a bypass line around the regulating valve. Extending the boildown period beyond 30 minutes or until the residue level drops below the steam coils could cause encrustation of contaminants on the steam coils. The coils would then have to be removed and cleaned in a caustic solution. Otherwise, solvent evaporation would be seriously impeded. After boildown, the liquid residue is drained from the boiling chamber and still operations are resumed. According to a still manufacturer, still boildown is typically required when the solvent and water flow from the condenser are reduced by 65 to 75 percent (Washex, 1973; Rosenthal, 1980). The boildown period should be terminated when the solvent flow from the condenser is reduced by 65 to 75 percent. This flow reduction is subjectively determined based on the operation of a particular still. Flow reduction is indicated by observation of sight glasses in the solvent lines between the boiling chamber and the condenser, as well as at the solvent outlet of the separator.

The frequency of boildown is a function of the size (volume) of the boiling chamber sump and the location of the steam coils within the

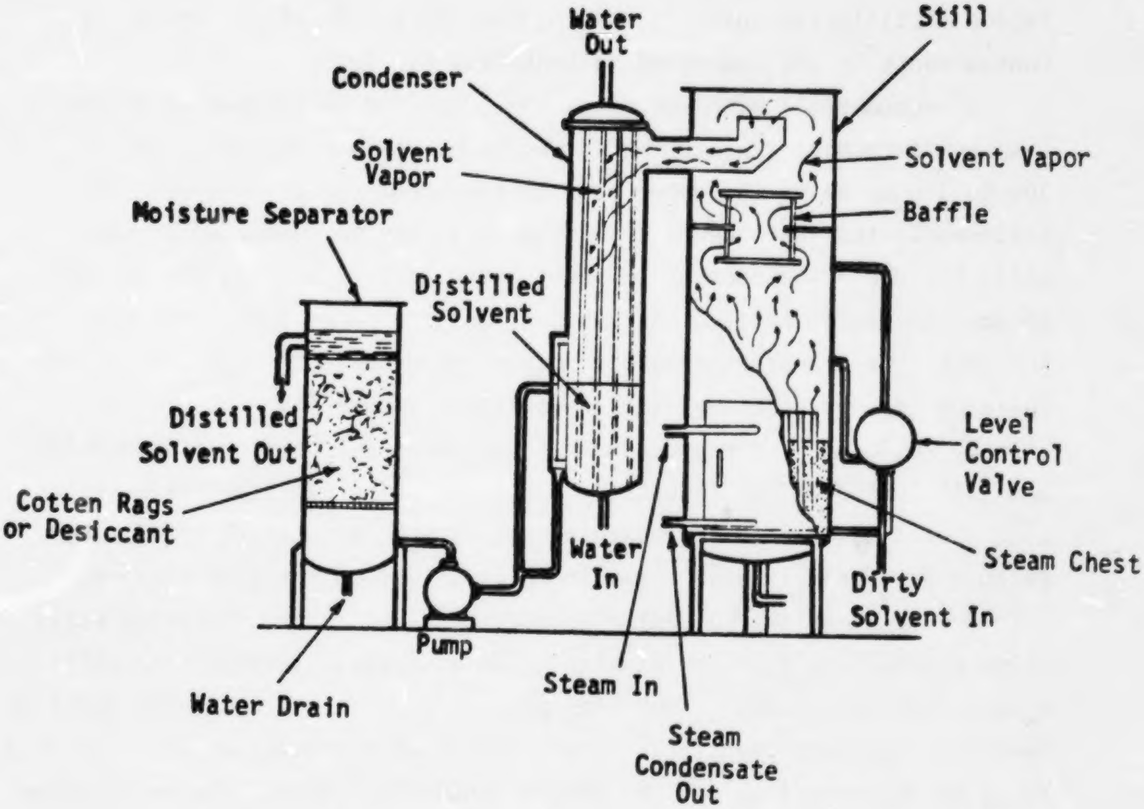


Figure 3-7. Vacuum Still Diagram.

boiling chamber. A still with a small capacity sump would have a higher boildown frequency than a similar capacity still with a larger sump. This is because the level of residue will increase at a faster rate in the smaller sump. A float valve maintains a solvent level of 100 to 150 mm (4 to 6 inches) below the top of the steam chest in a typical modern still. The purpose of exposing the upper part of the steam chest is to volatilize the foam created by the boiling process. Foaming results from water in the solvent inflow flashing to steam which could impede distillation while increasing the carry-over of oil and other contaminants in the condensed solvent (Washex, 1973).

A vacuum still with the steam chest located in the bottom of the sump would require frequent boildowns to maintain a solvent level of 100 to 150 mm below the upper part of the steam chest. However, if boildown is too infrequent, the steam coils may be submerged in the still residue, with much of the heat being lost in heating the residue. Because the still residue has a higher boiling range than petroleum solvents, the transfer of heat from the steam coils through the residue would be impeded, thereby limiting solvent evaporation.

By following these procedures for solvent evaporation/condensation and still boildown, an industry trade association representative states that a well maintained and operated unit should distill 15 to 30 liters (4 to 8 gallons) of solvent per 45 kg (100 lbs) of articles cleaned, with 3 percent of the solvent distilled retained in the discarded still waste (Fisher, 1975). An industry trade association analysis of still wastes from 43 separate commercial petroleum dry cleaning plants revealed that well operated plants can reduce the solvent content of still residue to 31 to 38 percent solvent by weight (Andrasik, 1981). (Three of these samples had solvent contents that were below 31 percent solvent by weight.) Although the trade association was unable to give the number of samples that achieved the various levels of solvent retention, the average range of solvent retention for all the samples was 39 to 42 percent solvent by weight. Samples with a solvent retention range of 43 to 51 percent were considered moderately high in solvent content, and samples with solvent contents that exceeded 51 percent were considered extremely high, indicating a poorly operated still (Andrasik, 1981).

Most dry cleaners boil down their stills at intervals based on convenience (i.e., boildown once a day or other predetermined rate) which may account for the high volume of solvent retained in the residue. In an EPA test of a vacuum still at an industrial petroleum dry cleaning plant, the solvent content of the discarded still waste exceeded 100 percent solvent by weight (Jernigan and Kezerle, 1981). This still was boiled down at the end of each day. When the frequency was reduced to one boildown in 10 days the weight of solvent in the residue decreased to approximately 80 percent by weight.

The size of the vacuum still or the sector application (commercial or industrial) should have very little effect on the proportion of solvent retained in the residue. This is due to the fact that the design of a vacuum still is identical for commercial or industrial applications. Although the content of high boilers in an industrial still could be more than that of a commercial still, reductions in still waste solvent content should be possible by boiling down only after the solvent flow is reduced by 75 percent and by terminating boildown only after the flow has again been reduced by 75 percent.

There are a number of factors that will affect the operation of a vacuum still. A continuously operated still is more efficient and cost effective than a comparable still that is operated intermittantly. In a continuously operated still less heat in required to maintain a sufficient temperature to adequately evolve solvent from the boiling chamber. In contrast, the intermittently operated still requires more heat (steam) because of the high frequency of start-ups. At the onset of start-up, much of the heat required is used to increase the temperature of the still and its contents to a uniform level. During a given time period, an intermittently operated still will evolve less solvent than a continuously operated still. Consequently, an intermittently operated still would have a higher solvent content in its still residue than a continuously operated still.

The efficiency of a still decreases proportionally to the increase in soil loading of the incoming solvent. Solvent entering a still with a high content of suspended particles, oils and grease will drastically reduce the distillation efficiency and useful life of the still. Because a vacuum still has a limited operating range of temperature and pressure, the degree of solvent contamination could increase the boiling range of this mixture beyond the temperature limits of the still. In this situation, little, if any, solvent is evolved from the still. Solvent entering a still from a cartridge filter will have less suspended contaminants than solvent from a diatomite filter. The diatomite filter would have less suspended contaminants than solvent from a settling tank. This problem of wide variations in soil loading can be alleviated somewhat by increasing the frequency of boildown with the increase in solvent contamination.

Water in the incoming solvent will produce a foaming action in the still. This foaming action will reduce the vacuum in the still, thereby reducing the solvent evolution rate. There is very little that can be done to remove the water from the solvent because it is inherent in most dry cleaning operations.

A vacuum still should always be operated within the manufacturer's recommended levels for steam pressure and temperature. Otherwise the evolution of solvent will diminish and undesirable fractions of liquids will mix with the distilled solvent.

The condenser water flow, between 8 and 30 liters (2 to 8 gallons) per minute, and temperature, between 16 and 27°C (60 and 80°F), are not very crucial items because the vaporized solvent will condense over these ranges of temperature and flow rates. However, condenser water temperatures greater than 27°C with flow rates less than 8 liters per minute would reduce the vacuum in the system such that a sufficient boiling temperature could not be maintained (Washex, 1973).

It can be inferred from the previous discussion that commercial vacuum distillation procedures should be more efficient than industrial distillation procedures, assuming that both stills are operated continuously and the soil loading is greater in industrial plants. Also, commercial vacuum stills should have less solvent retained in their still waste than an industrial vacuum still when both are operated under identical conditions.

3.3.5 Fugitive Emission Sources

There are a number of sources of fugitive emissions in a dry cleaning operation. Fugitive sources typically include emissions from the extraction cycle of a washer, emissions given off during the transfer of solvent-laden articles from washers and dryers, emissions resulting from solvent remaining in articles removed from the dryer, liquid and vapor leaks in tanks and piping, and the evaporation of solvent from open containers. Also included are fugitive emissions from filter muck, still, and settling tank residue which may be stored in open containers prior to disposal. Although many sources of fugitive emissions can be identified, (i.e., pumps, tank vents, and piping) and the VOC concentrations within the vicinity of these sources can be quantified, it is virtually impossible to estimate an emissions rate for most fugitive sources.

In an EPA test to determine fugitive emissions at a large industrial dry cleaning plant, it was found that more than 0.5 kg VOC per 100 kg dry weight of articles cleaned was emitted from various sources within the plant (Jernigan and Kezerle, 1981). Emissions were expected to be higher than those recorded because the doorways and windows (pathways through which emissions escaped to the atmosphere) remained open during fugitive testing. It is not technically and economically feasible to quantify all sources of emissions in a dry cleaning plant. This is because certain emissions are prevalent only during the operation of the dry cleaning equipment, while other (difficult to detect by instrumentation) low-level sources emit continuously. A dry cleaning industry trade association publication assumes, however, that miscellaneous (fugitive) emissions are nominally 1 kg of VOC emissions per 100 kg dry weight of articles cleaned (Fisher, 1975).

3.4 BASELINE EMISSIONS

The baseline emissions level for the petroleum solvent dry cleaning industry is the level of emission control that is achieved by the industry in the absence of additional EPA standards. This section presents the logic and rationale leading to the selection of the baseline emission level. The baseline level is established to facilitate comparison of the economic, energy, and environmental impacts of the regulatory alternatives (See Chapters 6, 7 and 8). A brief description of existing regulations that limit emissions from facilities within the affected industry is presented. Generally, the regulations of interest are the Control Techniques Guideline (CTG) document and the State Implementation Plans (SIPs).

3.4.1 Existing Regulations

The future issuance of the Control Techniques Guideline (CTG) has the greatest potential for impacting the NSPS baseline emissions. This EPA document is distributed to the individual states in an effort to provide a common data base for the development of the individual SIPs. In the current draft CTG for the Petroleum Dry Cleaning Industry, it is recommended that only large size plants be regulated (potential 100 metric ton emitters). These facilities should install solvent recovery dryers, install cartridge filters (where solvent filtration is used), and implement improved operating and maintenance procedures to minimize emissions from stills, settling tanks, and fugitive sources.

The impact of the future CTG on the NSPS baseline is a function of the number of SIPs adopted at the time of NSPS proposal and the proportion of the SIPs that will adopt the emission control technology outlined in the CTG. This latter group of states will not meet the December 31, 1982 statutory deadline for demonstration of attainment of National Ambient Air Quality Standards for ozone. At this time, however, it is impossible to make a reasonable estimate of the number of petroleum dry cleaning plants in the non-attainment areas and the localities that will write regulations. Thus, the impact of the CTG on the SIPs and their impact on the NSPS baseline emissions has not been determined in this document.

3.4.2 Calculation of Baseline Emission

Baseline emissions calculations are based on EPA field test data and on information supplied by dry cleaning trade association representatives. As previously discussed, standard dryer drying cycle VOC emissions were found to be 14 kilograms and 28 kilograms VOC per 100 kilograms articles cleaned in two EPA tests. An industry trade association reported standard dryer emissions as 14 kilograms VOC per 100 kilograms articles cleaned. Thus, the range of baseline dryer VOC emissions is 14 to 28 kilograms per 100 kilograms articles cleaned. Based on an average of the data from the three tests, the nominal value of standard dryer drying cycle emissions is 18 kilograms VOC per 100 kilograms articles cleaned. Solvent recovery dryers have not been included in the baseline because there are relatively few in operation in proportion to the current number of standard dryers, because the impacts of the NSPS and CTG on dryer sales are difficult to determine at this time, and because the condensation recovery of petroleum solvent is a new dryer technology in the dry cleaning industry.

VOC emissions produced by the disposal of spent cartridge filter elements were found to be less than 0.5 kilograms VOC per 100 kilograms articles cleaned in an EPA field test. Additionally, a dry cleaning trade association determined that VOC emissions from cartridge filters are approximately 0.8 kilograms VOC per 100 kilograms articles cleaned. Consequently, the baseline range for cartridge filter emissions has been established as 0.5 to 1.0 kilograms VOC per 100 kilograms articles cleaned, with nominal cartridge filter emissions being 1.0 kilogram VOC per 100 kilograms articles cleaned. Diatomite filters (and devices related to diatomite filter muck processing) are not included in the baseline because, as previously discussed, both industry trade associations and equipment manufacturers indicate that the trend in facilities utilizing solvent filtration has been toward the installation of cartridge filters. Thus, a plant buying a solvent filter would tend to choose a cartridge filter.

Vacuum still VOC emissions were estimated to range from 1 to 3 kilograms VOC per 100 kilograms of articles cleaned in a dry cleaning trade association report. However, an EPA field test of a vacuum still found emissions to be as high as 7 kilograms VOC per 100 kilograms articles cleaned. Because of the diversity of the emissions reported in the trade association analysis, the range of baseline vacuum still emissions was established at 1 to 7 kilograms VOC per 100 kilograms articles cleaned. However, the nominal emission value was set at 3 kilograms VOC per 100 kilograms articles cleaned based on the highest emissions reported by the trade association.

Fugitive VOC emissions measured in an EPA field test were approximately 0.5 kilograms VOC per 100 kilograms articles cleaned. An industry trade association estimated these fugitive emissions to be approximately 1.0 kilogram VOC per 100 kilograms articles cleaned. Therefore, the nominal baseline fugitive emissions value has been established as 1.0 kilogram VOC per 100 kilograms articles cleaned, representing the maximum emissions reported by the industry trade association.

Baseline emission rates discussed above are summarized in Table 3-2. Totals of both ranges and nominal values are given, thereby indicating the total emission rates that could be encountered in plants having all or some of the equipment listed. In general, the most common variation (See Chapter 6 for a discussion of model plants) is the omission of solvent filtration in some large plants with high throughputs and heavy soil loadings. In these facilities, settling tanks are used prior to distillation, and the emissions resulting from these tanks are included under the general category of fugitive emissions.

Table 3-2. BASELINE VOC EMISSION RATES
(in kilograms VOC emitted per 100 kilograms articles cleaned)

Affected facility	Emissions range	Nominal emissions
Standard dryer	14 - 28	18
Cartridge filter	0.5 - 1	1
Vacuum still	1 - 7	3
Fugitive emissions	0.5 - 1	1
Total	16 - 37 (15.5 - 36)[a]	23 (22)[a]

[a] Total VOC emissions in plants using settling tanks insteam of cartridge filters.

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4. EMISSION CONTROL TECHNIQUES

Equipment and procedures selected as representing currently available emission control technology for the petroleum dry cleaning industry are described in this chapter. Particular attention is given to the design, operation, and VOC emission-reduction performance of this equipment. The verification of these criteria is supported, where possible, by engineering analyses and field test data.

4.1 DRYER EMISSION CONTROL TECHNIQUES

There are only two techniques for dryer VOC emission control that have been demonstrated in actual use in petroleum solvent dry cleaning plants: recovery dryers and carbon adsorption. While recovery dryers have been in use in petroleum dry cleaning plants since about 1978, carbon adsorption equipment has been used in only one petroleum dry cleaning plant. Both of these dryer emission control techniques are discussed in the following subsections.

4.1.1 Recovery Dryer

A solvent recovery dryer is essentially a standard dryer that has been fitted with a condenser to remove solvent vapor from the dryer exhaust by condensation (see Figure 4-1). In the current configuration of this machine, a steam-heated air stream is directed around and through a tumbling load of drying articles by a blower. The solvent-laden air stream is forced through a lint filter and then to a condenser. After partial removal of both solvent and water vapors in the condenser, the air stream is ducted from the condenser to a steam chest where it is reheated. The reheated air stream then passes to the tumbler where the cycle of solvent evaporation repeats. In contrast, a standard dryer forces heated air through the tumbling articles and then exhausts it to the atmosphere.

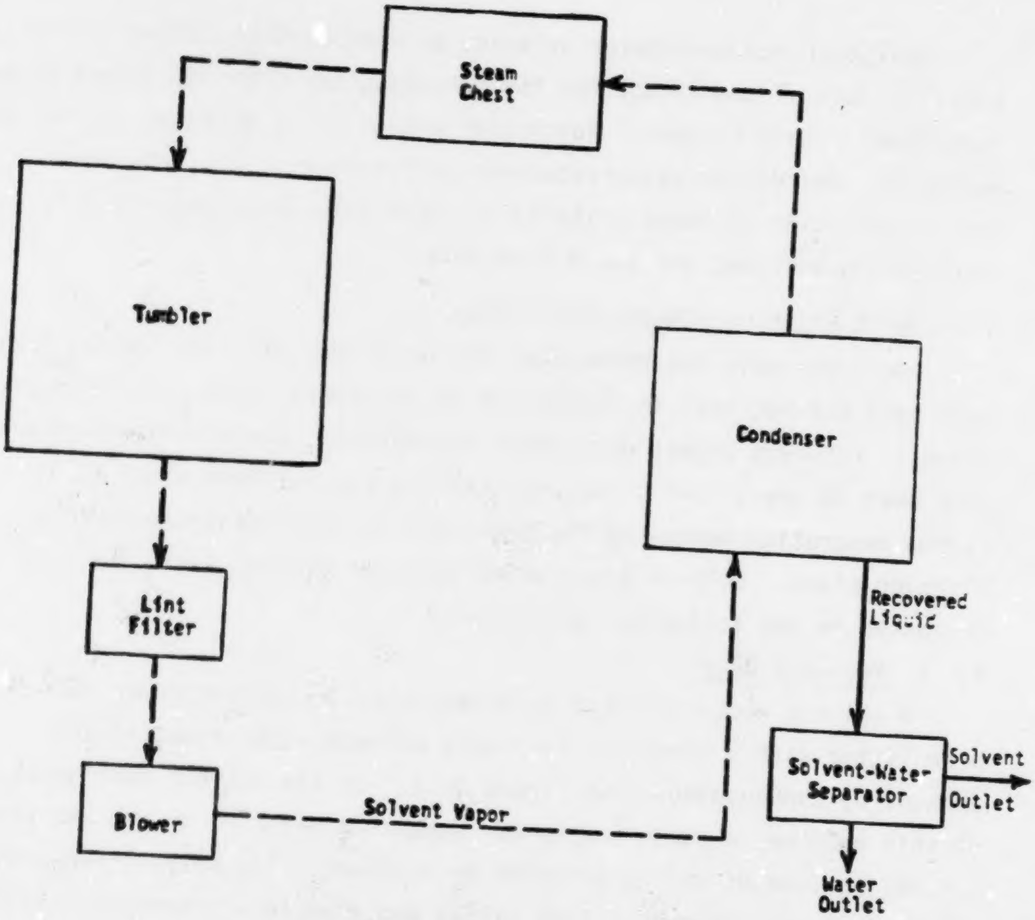
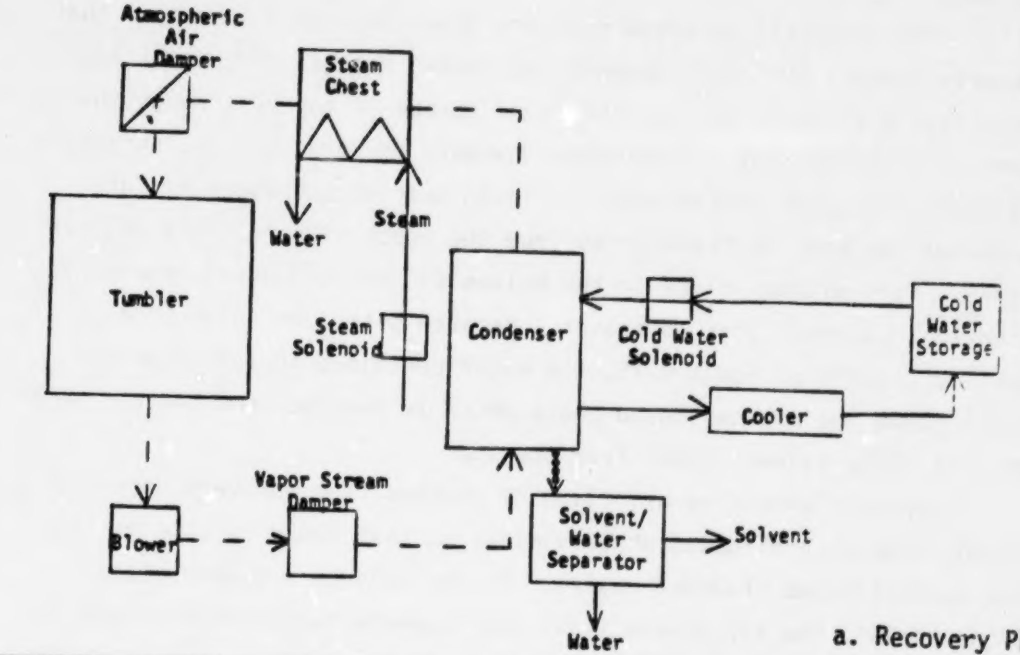


Figure 4-1. Solvent Vapor Flow Diagram for a Recovery Dryer.

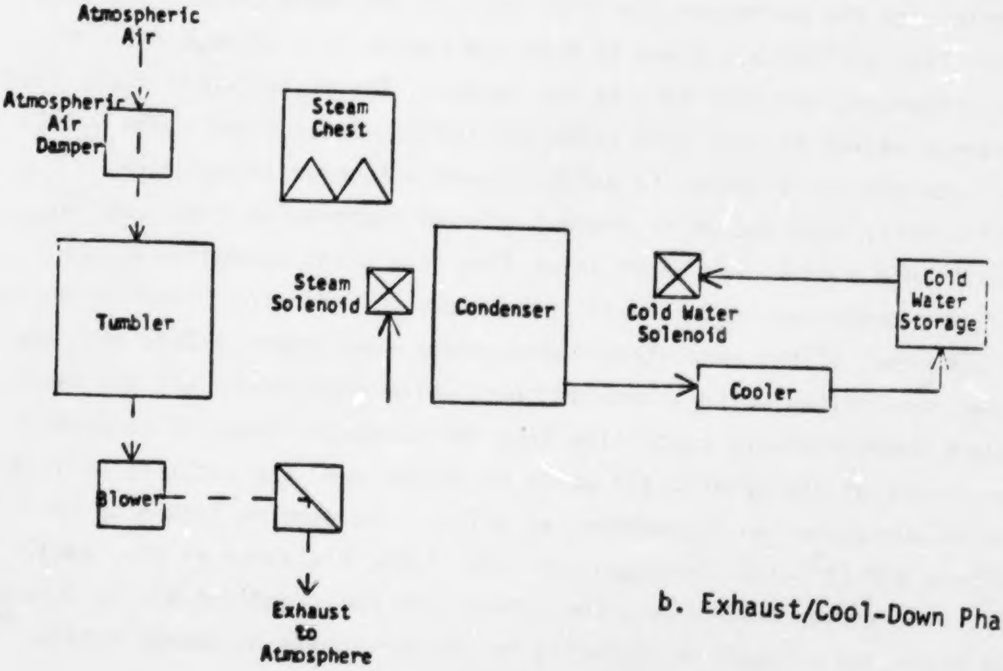
The most important component of the solvent recovery system is the condenser, which gradually reduces the concentrations of both solvent and water vapors in the air stream during every evaporation-condensation cycle. The currently marketed recovery dryer employs a condenser that steadily reduces the vapor temperature (under the existing conditions of vapor flow and pressure). As the vapor stream is forced through the condenser, chilled water circulates downward through the tube structure and cools the vapor stream until a liquid solvent and water mixture condenses (as heat is transferred from the vapor stream to the chilled water). This mixture flows to the bottom of the condenser where it is piped to a solvent/water separator. Because petroleum solvent has a specific gravity of about 0.75, the water contained in the condenser runoff forms the bottom liquid phase which is removed from the bottom of the unit while solvent flows from the top.

To prevent excessive wrinkling of clothes, the recovery dryer has a second, exhaust/cool-down, phase similar to that found in some of the more sophisticated standard dryers. In the solvent recovery phase (Figure 4-2a), the air stream flows (at a manufacturer-rated volumetric flow rate of 17.7 m^3/min (Hoyt, 1979)) from the steam chest through the tumbler, to the condenser, and then back to the steam chest. The cooling water flow during this phase is from the cooler to a storage tank, to the condenser, and then back to the cooler. Thermostatically controlled solenoid valves control both steam and cooling-water flows. The valves are intermittently opened to maintain both a tumbler temperature sufficiently high enough to promote solvent evaporation from tumbling fabrics and a condenser water inlet flow rate great enough to ensure adequate condenser heat-removal for optimum VOC emission reduction/recovery. At the onset of the exhaust/cool-down phase (see Figure 4-2b), both the steam and cooling water solenoids close while atmospheric air and vapor stream dampers divert vapor flow from the condenser loop. This permits the intake of atmospheric air which is forced over the tumbling articles and exhausted to the atmosphere, at a flow rate ranging from 9 to 13 m^3/min (300 to 450 ft^3/min) (Jernigan and Lutz, 1980; Plaisance et al., 1981).

In the open door phase, the exhaust fan pulls ambient air in through the dryer and exhausts it directly to the atmosphere at approximately



a. Recovery Phase



b. Exhaust/Cool-Down Phase

Figure 4-2. Operating Cycles of the Existing Recovery Dryer.

22 m^3/min (750 ft^3/min). Thus, solvent vapor escaping from the articles being loaded and unloaded is removed from the operating area (Hoyt, 1979).

Control of the duration of the drying and exhaust/cool-down phases is accomplished by two timers that can be individually set for a wide range of recovery and exhaust/cool-down periods. Typically, the duration of the recovery phase ranges from 20 to 45 minutes, while that of the exhaust/cool-down phase ranges from 2 to 6 minutes (Plaisance et al., 1981). Thermostatically controlled shutoff valves that govern tumbler temperatures (steam flow) and condenser water inlet temperatures (water flow) can be adjusted to protect drying articles from overheating and to maintain optimum VOC emission reduction/recovery. A manually-adjustable valve in the condenser water inlet line permits regulation of the water flow rate. A manually-adjustable pressure control in the steam chest inlet provides a controlled steam pressure for the heating of the vapor stream.

In the event of an explosion in the dryer, the pressure of the blast is released upward from the tumbler through vents specifically designed for this purpose, while steam is automatically injected into the tumbler. In addition, a fusible wire spanning the condenser vapor inlet will melt above a predetermined temperature, shutting down the electrical system and terminating dryer operations.

The level of emission reduction attained by the recovery dryer is based on the assumption that all solvent entering the dryer in garments is either recovered or emitted to the atmosphere during the cool-down/exhaust phase (in contrast to standard dryers which emit their entire solvent content to the atmosphere). Thus, the VOC emission reduction is equal to solvent recovery. This assumption neglects the solvent emitted during the open-door phase, as well as that contained in the articles after drying. Furthermore, it is assumed that garments leaving the dryer are "dry" (contain no solvent), and that there are no random or unspecified losses within the evaporation-condensation system. (Results of recovery dryer field tests are inconclusive concerning the solvent content of dried items, due to the difficulty of differentiating between residual solvent and water. However, there are indications that drying time, load weight, fabric type, and condenser temperature and flow (both vapor and liquid) all cause variations in the solvent content of dried articles.) Based on these assumptions, the recovery dryer performance parameters of primary importance are VOC emission reduction and solvent recovery.

Three EPA test programs have been completed at facilities operating domestically manufactured 48 kg (105 lb) capacity recovery dryers. A summary of the results of the three test programs is presented in Table 4-1. A more complete discussion and detailed description of the three tests and their results can be found in Appendix C of this report or refer to the cited references.

The first test (Test A) was conducted at a large industrial dry cleaning facility that processes approximately 1,300 kg (2,900 lbs) of heavy work gloves each day (Jernigan and Lutz, 1980). Results from the measurement of the vapor concentration and flow rate during the exhaust/cool-down phase were an average (for the entire test period) dryer VOC emission of 0.96 kg VOC per 100 kg dry weight of articles cleaned. The condenser reclaimed an average of 23.4 kg of solvent per 100 kg articles cleaned. The dryer appeared, at times, to operate at or above 90 percent of the 10,000 parts per million LEL concentration for petroleum solvent (as measured at the condenser vapor inlet during the recover phase). However, the existence and extent of the excursions above 90 percent were not verified because the solvent concentrations exceeded the capacity of the detection instrument. Possible explanations for this apparent excursion center around the fact that the dryer was typically loaded beyond manufacturer's specifications (by as much as 20 percent), with articles (gloves) having an unusually high solvent retention of as much as 30 percent by weight (Jernigan and Lutz, 1980).

A second EPA recovery dryer test (Test B) was undertaken at a large commercial plant that processes approximately 180 kg (400 pounds) of general apparel each day (Jernigan et al., 1981). Again, solvent vapor concentrations in the condenser vapor inlet and atmospheric exhaust were monitored, as were the flow rate and mass of recovered solvent. The average (over the test period) exhaust cycle VOC dryer emissions vented during the exhaust cycle were found to be 3.85 kg VOC per 100 kg dry

Table 4-1. SUMMARY OF RECOVERY DRYER TEST RESULTS

Test site	Type of articles cleaned	Number of dryer loads tested*	Recovered solvent (kg/100 kg of articles)		Exhaust emissions (kg/100 kg of articles)	
			Range	Average	Range	Average
Test A	Industrial (Gloves and fender covers)	13	15.5-29.2	23.4	0.68-1.25	0.96
Test B	Commercial (Personal clothing)	26	8.8 -14.3	10.4	2.34-9.45	3.85
Test C	Commercial (Personal clothing)	40	9.5 -17.7	13	1.20-7.2	3.47

Test A Jernigan and Lutz, 1980. [Pico Rivera].
Test B Jernigan, May, and Plaisance, 1981. [Lakeland].
Test C Plaisance, Jernigan, May, and Chatlynne, 1981. [Rhode Island].

* Number of dryer loads for which complete data were available to compute the recovered solvent and exhaust emissions averages.

weight of articles cleaned. The condenser reclaimed an average of 10.4 kg of solvent per 100 kg of articles cleaned. Solvent vapor concentrations in the condenser inlet stream never exceeded 95 percent of the solvent LEL and ranged from 4,410 to 9,425 ppmv as solvent. The reduced VOC emission reduction value was possibly due to the processing of small loads (typically 50-60 percent of dryer capacity) of garments (principally synthetics) having low solvent retention. Also, recovery periods were relatively brief (usually lasting no more than 30 minutes), resulting in the premature termination of the recovery phase and a corresponding increase in the solvent content of dried articles (Jernigan et al., 1981).

A third EPA recovery dryer test (Test C) was conducted at a large commerical plant that cleans about 2,700 kg (6,000 lb) of personal clothing per week (Plaisance et al., 1981). Both dryer condenser vapor inlet and dryer atmospheric exhaust concentrations were monitored, and data on the volume and flow rate of recovered solvent were collected. The average (for the test period) dryer VOC emissions vented during the exhaust cycle was 3.47 kg VOC per 100 kg dry weight of articles dry cleaned. The condenser reclaimed an average of 13 kg per 100 kg of articles cleaned. The average maximum solvent concentration in the dryer, during the recovery cycle, was measured as 3,100 ppmv, with a range of 2,800 to 3,500 ppmv. Dryer operating parameters such as load weight, fabric composition, recovery duration, and cooling water flow rate were varied to examine their effects on emissions, concentrations, and recovery. The weight of the wet articles placed in the dryer and the decrease in the vapor stream temperature in the condenser were found to have the greatest influence on solvent recovery and VOC emissions, with larger loads and greater condenser temperature decreases resulting in lower emissions and higher recovery. In addition, increasing the drying temperature inside the tumbler during recovery was found to increase the magnitude of the maximum solvent concentration in the exhaust. The measurement of these concentrations, however, was hampered by problems with both plant and testing equipment, resulting from very low ambient temperatures. The absolute magnitudes of these concentrations, when compared with previous test data, were extremely low and probably inaccurate (Plaisance et al., 1981).

The installation of currently-manufactured recovery dryers in existing petroleum dry cleaning plants would involve the replacement of standard dryers with recovery units. Although steam (2.5 boiler horsepower at 410 kilopascals) and electrical (1.5 motor horsepower at 230 volts) demands and connections would be similar for both units, the recovery dryer would require additional connections of pressurized air (0.04 cubic meters per minute at 275 kilopascals) and cooling water (Hoyt, 1979). The demand for cooling water in the 48 kg (105 lb) recovery dryer is typically satisfied by municipal water, a cooling tower, or a chiller with a minimum output capacity of 11.4 liters per minute (3 gal/min), and a temperature of 13°C (55°F) (Hoyt, 1979). Meeting these cooling water specifications in cool, dry climates may involve only a connection to municipal water or the installation of a relatively inexpensive cooling tower; however, hotter, humid climates may require the lower temperatures associated with a chiller. The chiller is inherently more expensive to buy and operate (costing up to 250 percent more than a cooling tower).

Proper operation of a currently manufactured recovery dryer would be based primarily on maintaining high VOC emission reduction/recovery. Adherence to dryer manufacturer's specifications in the areas of steam pressure, condenser water inlet flow rate and temperature, tumbler drying temperature, and tumbler load weight should ensure adequate performance and safety. Operating within the range of manufacturer's specifications, tests have shown that VOC emission reduction/recovery can be maximized by drying larger load weights (up to the rated capacity) while optimizing heat transfer within the condenser for a more complete removal of solvent from drying articles (Plaisance et al., 1981).

Heat transfer in the recovery dryer condenser was found to be at its maximum (defined as the highest average VOC emission reduction/recovery per dry weight of articles cleaned) when the temperature decrease of the condenser vapor stream was at its maximum (Plaisance et al., 1981). For a given drying temperature and cooling water flow rate, this optimum operating condition could be indicated by the temperature difference between the condenser cooling water inlet and outlet. According to the dryer manufacturer, the difference should not exceed about 15°C (27°F) during the recovery cycle (Hoyt, 1979).

Figure 4-3 illustrates a typical recovery phase that meets the conditions stated previously. The initial rapid solvent recovery gradually decreases to a near constant value (little or no additional recovery with time). During this dryer load, the average condenser water inlet and outlet temperatures are 21°C (70°F) and 30°C (86°F). The concentration of solvent vapor in the condenser gas inlet also is shown for the same recovery phase. Initial high concentrations correspond to rapid increases in the volume of recovered solvent; however, as the duration of the recovery phase increases, the concentration of solvent vapor tends to level off. This indicates a minimum recovery phase duration necessary for optimization of VOC emission reduction/recovery.

The recovery dryer solvent recovery rate data collected in the second large commercial plant recovery dryer test (Plaisance et al., 1981) was analyzed by EPA to evaluate the relationship between the flow rate of recovered solvent and the dryer emissions measured during the exhaust cycle. These data were selected for analysis because conditions of fabrics, load weights, recovery durations, and operating parameters varied over a range that might be typical in a large segment of the industry. The flow rate of recovered solvent at the end of each recovery cycle was calculated. A comparison of these results indicated that a final recovered solvent flow rate of 0.05 liters per minute was the highest value encountered in any of the loads examined. Although this value could not be correlated with a definitive VOC emissions value for the exhaust cycle, an analysis of graphs of the recovered solvent flow rate indicated that this 0.05 liter per minute flow rate could be used to indicate a point of diminishing returns (see Figure 4-2). Beyond this level additional recovery cycle time would produce only minimal increases in the volume of recovered solvent. This evaluation indicates that the 0.05 liter per minute recovered solvent flow rate could be used

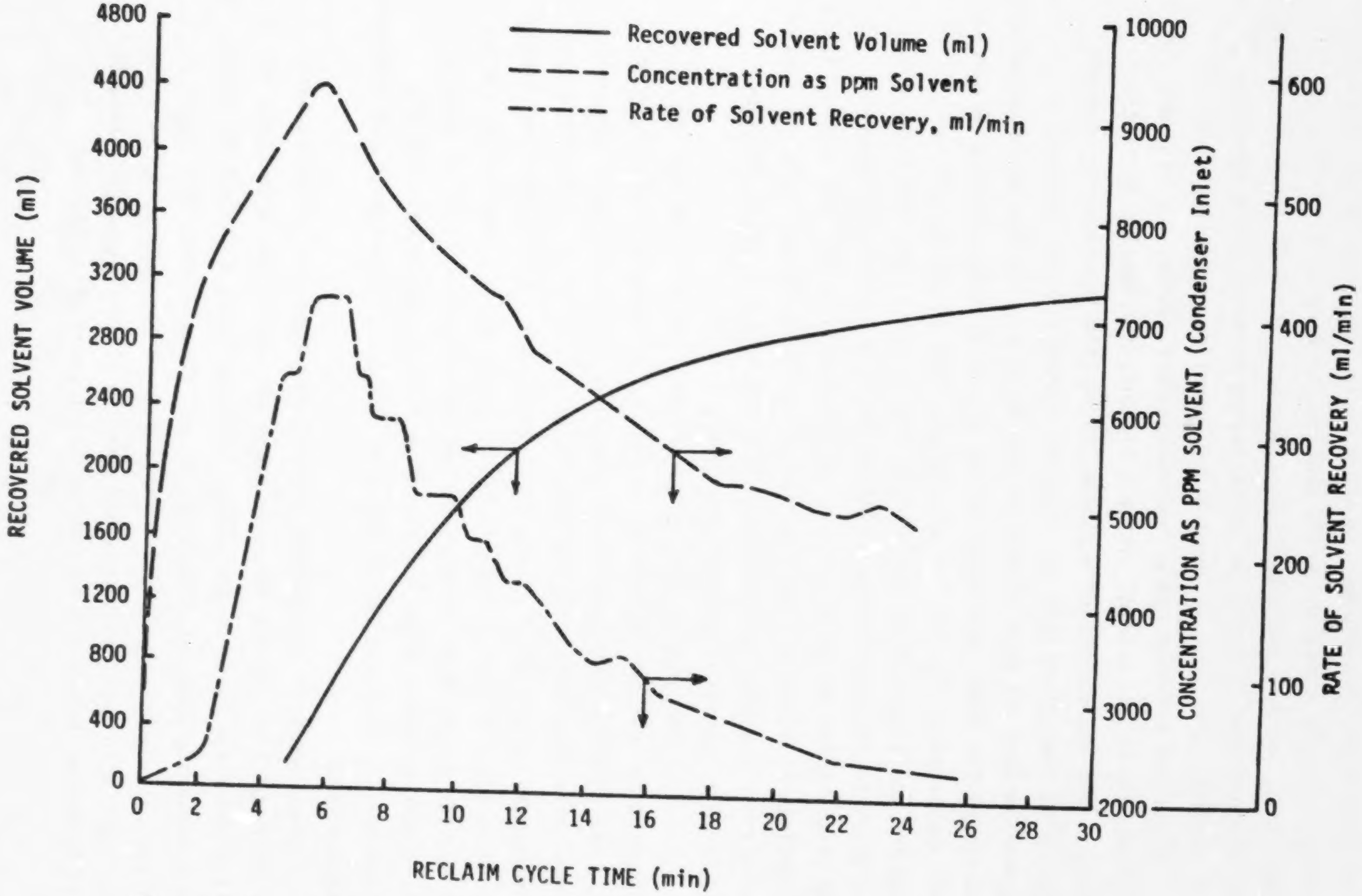


Figure 4-3. Solvent Recovery and Concentration Curves for the Recovery Dryer.

as an indication of a minimum recovery cycle duration. While the actual exhaust cycle VOC emissions would continue to vary as a function of load composition, weight, and operating parameters, the 0.05 liter per minute rate could provide a basis for establishing recovery cycle durations that reflect variations in loading and operating parameters.

Floor and overhead space requirements are similar for standard and recovery dryers and present little difficulty for smaller facilities; however, the replacement of a single 180 kg (400 lb) capacity standard dryer with four 48 kg (105 lb) capacity recovery dryers (currently, recovery dryers are made in only 23 and 48 kg capacities) would necessitate increasing the floor area required for dryers by approximately 30 percent from approximately 28 to 37 square meters (300 to 400 square feet). The need for additional floor space could force some large industrial plant operators to restructure the layout of their dry cleaning equipment. It may also require an addition to an existing building or the acquisition of additional space by lease, purchase, or construction. Most of these facilities, however, should have sufficient space in their existing plants to accommodate the recovery dryers.

4.1.1.1 Recovery Dryer Safety. Solvent recovery by chilled condensation is a new technology as applied to petroleum dry cleaning. Only one domestic manufacturer is producing recovery dryers. Because these units have been produced domestically only since 1978, there are fundamental questions of safety to be addressed. These questions center on three major topics which will be discussed below: the concentration of solvent in the dryer tumbler during recovery, the ignition sources associated with the dryer and the effects of an explosion, and the acceptability of the dryer to agencies such as fire marshals and insurance underwriters.

Measurement of the maximum solvent concentration in the recovery dryer tumbler during the recovery cycle was one of the objectives in all three EPA field tests of the unit. Unfortunately, difficulties associated with measuring high concentrations of petroleum solvent in a vapor stream cast doubts on the validity of much of the data obtained. The only test with reasonably accurate maximum concentration measurements was conducted in a plant that dried small loads of synthetics. This plant is atypical of most of the industry. In the only test of a recovery dryer in an industrial plant, the concentration-measuring instrument (FIA) became saturated with solvent and continued to register a concentration of 9,000 ppmv. The actual concentration in the dryer apparently continued to increase and probably exceeded the solvent lower explosive limit (LEL) of 10,000 ppmv (Ashland, 1977). In the third test, the difficulty of preventing solvent vapor condensation in the FIA sample lines produced unrealistically low readings of maximum concentrations. Although there are no test data showing dryer concentrations in excess of the solvent LEL, an examination of the existing data indicates that there is a high probability, depending on the weight of articles being dried and the drying temperature, that the concentration of solvent in the tumbler does exceed the solvent LEL at some point in the recovery cycle. While this condition would not occur in every drying load, it would tend to occur in larger facilities where large loads would be dried at higher temperatures to decrease the overall drying time.

Possible sources of ignition in the recovery dryer are limited to static electricity and flammable objects (matches and lighters) contained in the drying articles. Dryer wiring and controls are contained in enclosures that meet or exceed National Fire Protection Association (NFPA) regulations for dry cleaning dryers. The dryer tumbler is fitted with a grounding system which, when properly grounded, should dispell static electricity. As a consequence of these design features, the primary source of ignition would be flammable objects, which should be removed from articles prior to washing. Flammable objects could be a significant problem in smaller plants that process personal articles or uniforms. However, static electrical spark would present the greatest problem in large plants that might process large volumes of static-prone material such as felt or synthetics.

If the solvent concentration in the recovery dryer tumbler reaches and exceeds the solvent LEL and an ignition source is present and active, an "explosion" can occur. The characteristics of a recovery dryer "explosion" follow a stepped process. First, the solvent vapor around the point of ignition burns very rapidly (flashes), and the line of vapor combustion (or flame front) spreads rapidly through the tumbler.

The extremely rapid pressure increase brought about by the vapor combustion opens the spring loaded explosion dampers on the top of the tumbler, instantaneously releasing the excess pressure. The dampers close to prevent inflow of air that would support further combustion. At the same time, a set of weights attached to one of the dampers activates both a valve that injects steam into the tumbler and a switch that stops the vapor circulation blower. Thus, while the force of the vapor explosion is released and directed upward away from personnel and other equipment, the occurrence of a fire in the tumbler is prevented by the elimination of combustion air and the injection of steam into the tumbler. (In contrast, the ignition of solvent vapors in older non-recovery dryers can, in the absence of fire suppression devices, results in fires which are fed by the continuous inflow of ambient air.)

Two recovery dryer explosions have been documented by EPA since production of the unit began (other explosions have been reported but specific details are unavailable). These explosions have been examined as to their causes and consequences. The first explosion occurred in December of 1979 at a commercial dry cleaning plant. According to the owner, the explosion took place during the drying of a 45 kg (100 lb) load of synthetic fabrics. The owner said there was a loud noise from the top of the dryer, and the tumbler basket was knocked out of alignment. The owner further explained that the dryer may not have been properly grounded. The synthetic fabric's high potential for static may have combined with the extremely low humidity at the time to produce a static spark. Damage resulting from the event was limited to the drying articles which were scorched and to the dryer (tumbler basket) which was replaced by the manufacturer.

The second recovery dryer explosion occurred in March 1981 at a small industrial dry cleaner. A load of felt grain mill filtration bags was being dried at the time. A member of the plant management explained that the combination of the high static potential of the felt material and the presence of grain dust probably combined to produce the explosion. This individual was standing about four feet from the dryer when it exploded. He described the effect as being like the sonic boom from a jet airplane. No personal injuries resulted from the explosion. Damage to the plant was limited to two plate-glass windows which were broken. The only damage to the dryer was disalignment of the tumbler basket shaft which was quickly realigned by plant personnel and tearing of the lint filter bag which was replaced. Of the 12 bags in the tumbler, only five had to be replaced due to minor scorching.

Because the technology of condensation recovery of petroleum dry cleaning solvent is relatively new, and because there are no statistics on dryer fires or explosions in the United States, the EPA conducted an examination of the design, performance, and safety of solvent recovery dryers in Japan (Jernigan, 1981). These dryers have been in use there for over five years, and their design and performance is very similar to that of the units manufactured in the United States. In both units, steam heated air evaporates solvent from drying articles. The solvent vapor is liquified and recovered by a refrigerant-chilled condenser. The main difference between the Japanese and domestic recovery dryer is that the dryer capacity is limited to 23 kg (50 lb) in Japan, with units having capacities of 10 kg (22 lb) being most prevalent. Throughout Japan, there are about 1,800 recovery dryers and 5,900 standard (nonrecovery) dryers. According to Japanese dryer manufacturers, there have been about 17 recovery dryer explosions and 50 standard dryer fires in the past five years. Thus, the frequency of explosions in recovery dryers has been almost identical to that of fires in standard dryers (about one occurrence per 1,000 dryers in the past five years).

The primary concern involved in the acceptance and approval of the recovery dryer by fire control agencies and insurance underwriters is the level of fire hazard inherent in the operation of the dryer. In order to gain this approval, the manufacturer has submitted the dryer for examination by Factory Mutual (a firm specializing in performance and safety testing). Factory Mutual has approved the unit and has included it in the 1981 published approval listing as the petroleum solvent dryer with current approval (Factory Mutual System, 1982). Further tests were observed in March 1982 by Factory Mutual that have reconfirmed their approval of the recovery dryer (Kennes, 1982). In addition, the dryer has received the general approval of the Los Angeles Fire Department (Los Angeles Fire Department, 1981).

A survey of dry cleaning plants that have installed the recovery dryer indicates that there have been no problems with insurability resulting from the operation of the recovery dryer (Corey, 1981). In general, insurance companies view the unit as another piece of dry cleaning process equipment and as such, insurance rates usually increase somewhat based on the addition of the dryer value to the overall facility. When underwriters insuring the dryer were questioned about the insurability of the unit, they generally said that approval by one of the major testing laboratories (Factory Mutual), together with approval by state and local fire officials, was sufficient to indicate that the dryer requires no specialized insurance coverage.

At the local level, a survey of fire marshals in areas where recovery dryers have been installed indicates that the unit's approval by Factory Mutual has resulted in initial acceptance by fire marshals who were aware of the dryer's presence (Corey, 1981). In most cases, however, the continuation of this initial approval was contingent on the frequency of explosions and accidents associated with the dryer. An increase in the number of dryer accidents could result in revocation of this approval.

In summation, the initial approval of the recovery dryer by individual dry cleaners, fire marshals, and insurance underwriters was based on the unit's approval by Factory Mutual and on its record of safety since 1978. Factory Mutual, in turn, has based its approval on the unit's ability to safely contain and control an explosion. This approval was made with the assumption that the solvent concentration in the dryer reaches and exceeds the solvent LEL and that an ignition source is present and active in the dryer (Kennes, 1981). Finally, the EPA has found no instances in which a fire marshal or insurance underwriter prohibited the installation of a solvent recovery dryer.

4.1.2 Carbon Adsorption

Carbon adsorption is a process in which one or more chemical constituents of a vapor stream are removed by circulation through and entrapment in a mass of activated carbon. The term "adsorption" refers to a submicroscopic process in which molecules of vapor become lodged in the porous carbon surface. The process results in the permeation of the surface with vapor condensate. As this condensate spreads over the available area, the surface is "blinded" to further adsorption, resulting in a state of "breakthrough". After breakthrough, there is only a minimal reduction in vapor concentration. At this point, a process known as "desorption" must be undertaken. During desorption, a vapor stream (steam or hot air) is passed through the carbon mass to re-vaporize and remove the adsorbed materials from the carbon. Unfortunately, the quantity of material removed from the carbon in desorption is never quite equal to that collected in adsorption. This results in a "heel" of entrained material that steadily decreases the area available for adsorption and ultimately renders the carbon useless.

While carbon adsorption technology is well-developed and in widespread use in industry, its application to dry cleaning has been limited to emissions reduction in plants using perchloroethylene solvent. Recently, however, an EPA test was undertaken in which a carbon adsorption system was successfully used to both reduce the solvent emissions from a petroleum solvent standard dryer and to recover the solvent in a reusable form (Lutz et al., 1980). This system will be used as a model for illustrating the design and performance of a carbon adsorber as applied to the exhaust vapor stream of a standard petroleum solvent dryer.

A carbon adsorption system, as applied to a dry cleaning dryer, is an add-on emissions control device. Solvent-laden vapors from the dryer exhaust (see Figure 4-4) are pulled through a bag filter where solid particles such as lint are removed. Once through the filter, the vapor is passed through an air cooler to remove excess moisture and prevent damage to the carbon beds by overheating. After this, the vapor stream is ducted to one or more adsorber vessels containing activated-carbon (see Figure 4-5). Depending on the quantity of carbon available for adsorption and the concentration of solvent in the adsorber vapor inlet, the adsorption cycle might continue for eight hours or more as solvent is entrapped in the carbon and the remaining air is vented to the atmosphere. As breakthrough is approached, the adsorber vessels are isolated from the dryer exhaust stream by valves (dampers) and a stream of low pressure steam is injected into each vessel. The steam flows through the solvent-laden carbon in a direction opposite to that taken by the dryer exhaust (see Figure 4-5). Transferring its heat to the

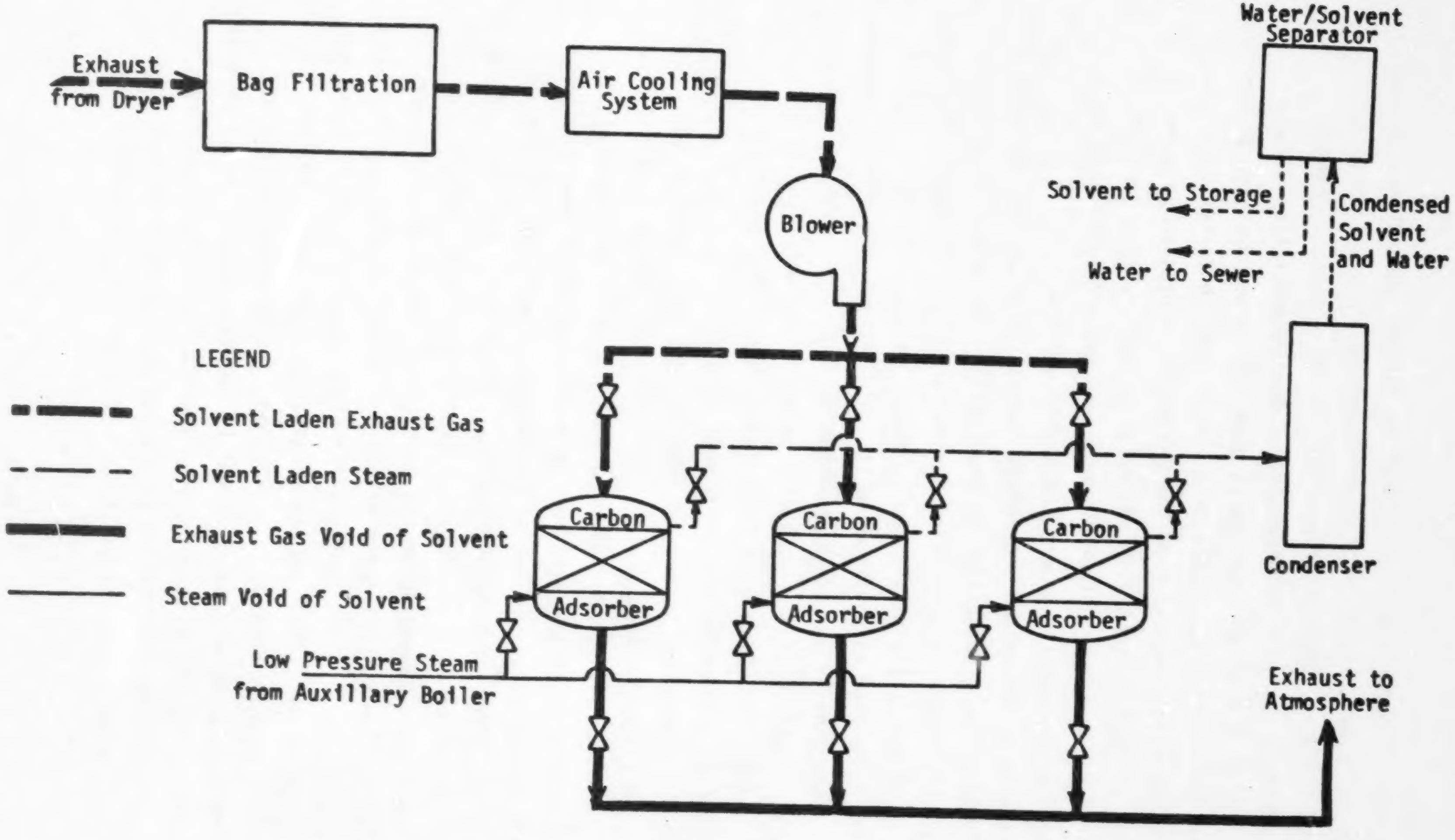
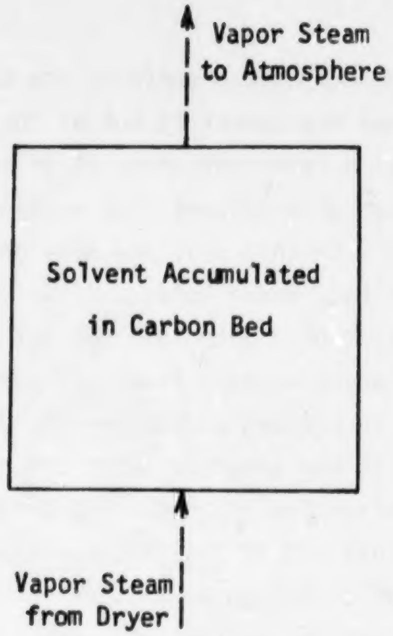
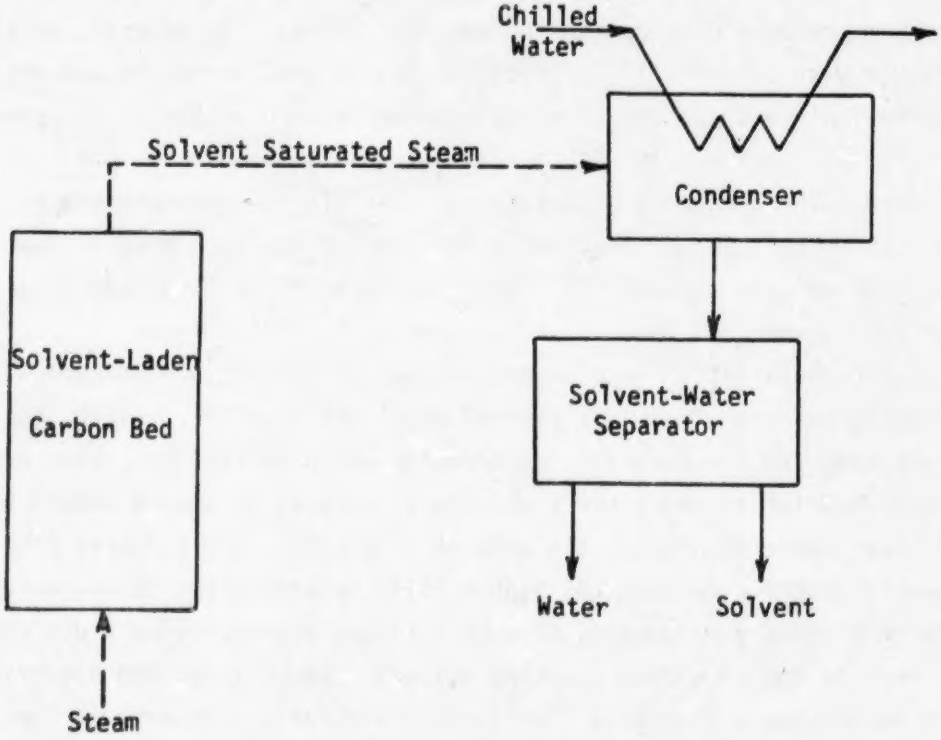


Figure 4-4. Carbon Adsorption System Schematic.



ADSORPTION



DESORPTION

Figure 4-5. Adsorption and Desorption.

liquid solvent coating the carbon surface, the steam mixes with the revaporized solvent and transports it out of the adsorber vessel. The mixture is ducted into a condenser where it is condensed to a liquid. Final separation of reusable solvent from wastewater takes place in a gravimetric separator. In this unit the more dense water is drained from the bottom while less dense solvent flows from the top.

The required "size" of a petroleum solvent carbon adsorption system is a function of the dryer exhaust flow rate and the desired emission reduction efficiency (expressed as the percent difference in solvent vapor concentrations at the adsorber inlet and outlet). The quantity of carbon required for effective adsorption is a direct function of the adsorber inlet flow rate and an indirect function of the solvent concentration. The distribution of this carbon in a number of adsorption vessels has a strong bearing on the frequency of desorption. Also, the high-flow, low-concentration vapor exhaust streams encountered in this application tend to necessitate carbon bed designs that result in a minimum pressure drop across the adsorber vessel. In general, vertical vessels with a high ratio of cross-sectional area to height are preferred; however, since this type of container may require costly custom fabrication, several smaller vessels with a similar cross-section-to-height ratio may be used. The frequency of desorption, therefore, is determined by the rate at which the individual adsorber vessels approach breakthrough: the more vessels sharing the load of adsorber inlet flow, the longer the periods between desorptions.

The installation of a carbon adsorption system in a petroleum dry cleaning plant would entail several major difficulties. First, the space required for adsorber installation would be critical, with even a highly-modulatized adsorber requiring as much as 20 square meters (200 ft^2) of floor space to process the exhaust of a single 180 kilogram (400 lb) capacity dryer. Second, the high utility (electricity, steam, water, and compressed air) demands of such a system might require a dry cleaner to replace and/or expand existing boilers, compressors, and electrical and water supply systems. Finally the relatively high exhaust flow rates found in most standard dryers, ranging from 60 cubic meters per minute (2,200 cfm) to 300 cubic meters per minute (10,000 cfm), necessitate the installation of a high-volume adsorber on a low-concentration source, thereby contributing to both the size and complexity of the system (Lutz et al., 1980).

EPA contracted the evaluation and demonstration of carbon adsorption technology at an industrial dry cleaning facility to determine the effectiveness of carbon adsorption in controlling VOC emissions. The test consisted of fitting a prototype carbon adsorption unit to the dryer exhaust of a petroleum solvent industrial dry cleaning dryer. Performance data were collected during the operation of the system. The economics of operation at this establishment were also evaluated. In addition, a long-term follow-up analysis of the emission reduction and recovery performance of the adsorber system was conducted in order to verify the efficiency and dependability of the system (Lutz et al., 1980).

The host dry cleaning plant was a large, industrial facility utilizing a 230 kilograms (500 lb) washer/extractor and a 180 kilograms (400 lb) dryer to process approximately 8,700 kilograms (19,000 lbs) of general apparel per week. This throughput represents about 50 percent of the 8-hour capacity of the dry cleaning dryer. Data were developed to determine the effect of the different utilization rates on the various parameters under evaluation. After installation of the carbon adsorption unit, testing was conducted at the facility from July 24, 1978 to March 23, 1979.

Test procedures used during the carbon adsorption test program included a determination of hydrocarbon concentrations by continuously sampling the gas streams to and from the carbon adsorption unit. This was accomplished using two Beckman 400 flame ionization analyzers (FIA). Both the inlet and exhaust gas stream flow rates were continuously monitored, as were the temperatures of the various liquid and gas streams. Other parameters measured during the test program included: electicity consumption, natural gas consumption, water usage, steam flow rate to adsorption unit, and solvent recovery rate. In addition, samples of solvent and carbon from the carbon bed were analyzed infrequently during the test period.

The carbon adsorber system (see Figure 4-4) was initially operated in strict compliance with the recommendations and instruction of the adsorber manufacturer and his field representatives. Early in this test period, it became apparent that the adsorption system had been overdesigned, resulting in removal efficiencies far in excess of the specified performance guarantee of 90 percent solvent removal on a 24-hour average. The test program was, therefore, amended to include an evaluation of changes to the design and operating procedures for the carbon adsorption system. Various design parameters were modified to determine their effect on the performance and cost of the adsorption system. From these studies, an optimized system was established for use in evaluating the performance, cost, and cost effectiveness of utilizing carbon adsorption technology for the reduction of VOC emissions from petroleum dry cleaning plants (Lutz et al., 1980).

The following alterations to the original adsorber design resulted from the optimization: (1) the lint filter area was increased by 80 percent to facilitate daily cleaning; (2) the blower that forces the dryer exhaust through the adsorber was modified to operate only when the dryer was running, rather than continuously; (3) the original system of three carbon beds was reduced to two beds; (4) desorption steam pressure, flow rate, and duration were optimized at 103 kilopascals, 590 kilograms per hour, and 60 minutes, respectively, (5) the adsorber inlet (dryer exhaust) vapor cooler was eliminated, because dryer exhaust temperatures were insufficient to damage the carbon beds; and (6) the quantity of carbon required for effective adsorption was found to be about 16 kilograms carbon for each cubic meter per minute of adsorber inlet flow (1 pound carbon per cfm of inlet flow).

The test-average hydrocarbon emission reduction efficiency for the initial evaluation of the optimized design (applied to the dryer exhaust) was 95 percent. This reduction efficiency varied from 93 percent for a plant with 100 percent utilization to 97 percent at 25 percent utilization. The test-average of solvent recovery efficiency was 84 percent. The recovery efficiency varied from 75 percent to 94 percent. The disparity between the emission reduction and recovery efficiencies of the solvent entering the adsorber was attributed to a combination of fugitive leaks in the adsorber system and to an accumulation of measurement errors.

The results of the follow-up EPA tests conducted in 1980-1981 indicate that the reduction in solvent concentrations from the adsorber inlet to the outlet ranges from 94 percent to 96 percent. Solvent recovery, however, ranged from 55 percent to 95 percent at the same time, and was found to be heavily dependent on the operating and maintenance procedures employed by the plant (Kezerle, 1981).

In an effort to explain this discrepancy, the drying system comprised of the dryer, adsorber, and associated equipment was analyzed as to their potential for non-specific or fugitive VOC emissions. Solvent losses from drying articles, based on load weights before and after drying, were found to average about 15 kilograms VOC per 100 kilograms articles cleaned. Fugitive losses occurring during drying were estimated at about 0.5 kilograms VOC per 100 kilograms articles cleaned. Consequently, only 14.5 kilograms VOC per 100 kilograms articles cleaned reached the adsorber inlet. It was estimated that an additional 0.5 kilograms VOC per 100 kilograms articles cleaned was emitted from fugitive leaks in the adsorber system prior to adsorption. At this point, the process of adsorption reduced the remaining solvent content of the vapor stream from 14.0 kilograms to 1.0 kilograms VOC per 100 kilograms articles cleaned. With approximately 13 kilograms VOC per 100 kilograms articles being entrapped in the carbon beds, the process of desorption resulted in estimated liquid solvent losses of about 0.5 kilograms VOC per 100 kilograms articles cleaned. Thus, only about 12.5 kilograms VOC per 100 kilograms articles cleaned was recovered in reusable liquid solvent. With the combined estimated losses considered as VOC emissions, the actual estimated emissions rate for the dryer/adsorber system was about 3.5 kilograms VOC emitted per 100 kilograms of articles cleaned (Kezerle, 1982).

The performance of a carbon adsorption system is dependent upon three principal functions: getting the solvent vapors from the dryer to the adsorbers; adsorbing the solvent in the carbon beds; and desorbing the carbon beds and recovering the solvent for reuse. The results of emissions testing and engineering observations indicate that most of the problems with the optimized demonstration adsorption system installed at the petroleum dry cleaning plant lie in the first and last principal functions. The adsorption of solvent by the carbon beds has been demonstrated to remain consistently above 90 percent and causes little problems with optimizing performance. Because of the pressure drop encountered in passing dryer exhaust gases through a carbon bed, conveying the solvent vapors from the dryer through the adsorber carbon bed requires a blower in addition to the fan in the dryer. This additional blower and ductwork creates the potential for vapor leaks or severe blockage due to lint. The system must be engineered so that all the exhaust gases leaving the dryer are filtered to remove lint, transported through the adsorber system without losses in flowrate, and delivered to the carbon beds at the proper temperature and pressure. Because both the concentration of solvent and the gas flowrate are very high upstream of the carbon beds, even a small leak in the duct system will result in a significant loss of solvent.

Once the solvent is adsorbed on the carbon it must be desorbed with steam, condensed, and separated from the water that results from the condensed steam. If the beds are not fully desorbed when required, solvent will build up in the beds and reduce their ability to adsorb more solvent. Eventually the beds will become saturated with solvent and will cease to adsorb any additional solvent vapors from the dryer exhaust gases. The three most common problems associated with desorption that reduce the performance of the beds are 1) not desorbing with sufficient steam pressure; 2) not desorbing for an adequate duration, and 3) not drying the beds with air after desorption is complete. Petroleum solvents require steam pressures of 205 kilopascals to 239 kilopascals (15 psig to 20 psig) for adequate desorption, with the higher end of this range being preferrable (Kezerle, 1981). The determination of adequate desorption and drying periods is dependent on the size of the carbon beds and other site-specific factors. Once these parameters have been determined, they must be adhered to rigorously. In a similar manner, the flowrate and temperature of water needed to condense the desorbed steam and solvent vapors must be determined for each installation and maintained at the proper levels. Sufficient drying in essential, otherwise the beds will be blinded with water which will prevent further adsorption. Finally, separating the condensed solvent and water must be done efficiently.

Allowing even a small percentage of solvent to escape with the drain water will lead to losses that are significant in terms of the total system.

In order to insure that the three functions mentioned in the previous section are performed correctly, certain operating parameters must be monitored and maintained at desired levels. Holding these parameters at the proper levels will maximize solvent recovery and, assuming whatever solvent is not recovered results in an emission, will indicate the minimum practical emission level.

Getting the solvent from the dryer to the carbon beds without losses can be verified by inspecting the system periodically for leaks. If permanent openings are designed into the system, as is the case with the demonstration unit, then duct pressures must be monitored to warn the operator when ducts are beginning to plug or other flow obstructions arise. These obstructions would be indicated by changes in the duct pressure during operation and should be removed promptly to assure good operation.

The adsorption of solvent by the carbon beds can only truly be measured by conducting hydrocarbon and gas flowrate testing at the inlet and outlet of the beds. It has been demonstrated that the carbon in the beds (of the demonstration unit) has an active life of at least three years. The manufacturer has estimated its active life at ten years. Therefore, testing of this type more frequent than once every three years appears to be unwarranted. A possible alternative, to assess the carbon's performance, is to periodically send samples of the carbon from the beds to the manufacturer. Most manufacturers will test the carbon's ability to adsorb and desorb solvent for no charge (Lutz et al., 1980; Kezerle, 1981).

The third function, desorption and recovery of solvent, is the most common source of operating problems. First, correct desorption parameters must be maintained. With the demonstration system this means:

a) use a desorption steam pressure of 205 kilopascals to 239 kilopascals (15 to 20 psig),
b) steam each bed at this pressure for no less than 55 minutes,
c) dry each bed for at least 30 minutes by blowing ambient air through it.

The operation of the condenser can be verified by maintaining set water flowrates and temperatures (inlet and outlet). Operation of the separator can be checked by collecting samples of the two streams that leave it. The amount of water in the solvent stream or solvent in the water stream should never exceed 0.5 percent on a volume basis (Kezerle, 1981).

The parameters cited above will verify proper operation of each component of the entire carbon adsorption system. An easier way to verify the proper operation of the entire system is to measure the volume of solvent recovered every time the beds are desorbed. The following equation could then be used to calculate the rate of solvent recovery.

Rate of solvent recovery =

$$\frac{\text{Volume of solvent recovered X Density of solvent}}{\text{Weight of material cleaned since last desorption}} \text{ X } 100$$

For the demonstration system the maximum potential rate of solvent recovery was calculated to be 11.95 kilograms of solvent per 100 kilograms of material cleaned. Solvent recovery rates close to this value were indicative of good operation of the whole system. However, this maximum potential solvent recovery rate is a function of the dryer, carbon adsorption system, and type of material being cleaned, and will differ for each installation of the adsorber (Kezerle, 1981).

4.2 FILTRATION EMISSION CONTROL TECHNIQUES

The primary VOC emissions from diatomite and cartridge filters, as discussed in Chapter 3, Section 3.3.2, result when solvent-laden filtration waste (either diatomite or used cartridges) is disposed in a manner that allows the entrained solvent to evaporate to the atmosphere. An industry trade association has estimated typical diatomite filter emissions to range from 5 to 10 kilograms VOC per 100 kilograms articles cleaned. This estimate is based on filter waste that has been allowed to drain for 24 hours (NID, 1971). Cartridge filter emissions due to evaporation of solvent from disposed cartridges were determined to be approximately 0.5 kilograms VOC per 100 kilograms artricles cleaned after 8 hours of both drainage and evaporation in an EPA test (Plaisance, 1981). An industry trade association has estimated VOC emissions from disposed filter cartridges to be approximately 1.0 kilograms VOC per 100 kilograms of artricles cleaned (NID, 1971). Thus, cartridge filters represent a VOC emission reduction over diatomite filters of approximately 80 to 95 percent.

Because of the wide availability of cartridge filters, their obvious advantages in reducing solvent losses (emissions), and the trend in the industry towards their installation cartridge filtration has the distinction of being both the baseline and control technology. It is assumed that a large number of existing plants utilizing solvent filtration have converted to cartridge filters. However, existing plants using other forms of solvent filtration (diatomite filters) and new plants intending to employ solvent filtration would benefit from the reduced solvent losses inherent in cartridge filters while producing substantial reductions in VOC emissions.

4.3 FUGITIVE EMISSION CONTROL TECHNIQUES

Fugitive emissions essentially encompass all sources other than dryers and filters. Vacuum stills, settling tanks, and miscellaneous emissions from tanks, pipes, and other equipment fall into this category.

Atmospheric emissions resulting from the operation of vacuum stills (see Section 3.3.4 for a distillation process description) are a function of the still design, operation, and the frequency of still utilization. To maintain the color (purity) of the solvent used in washing, a dry cleaning plant operator will often adhere to a still boildown schedule that requires solvent distillation at intervals ranging from daily to weekly. Also, the design of some stills is such that, regardless of the boildown period, there will be a fixed volume of solvent-laden residue at the end of the operation.

Specific operating and maintenance parameters cannot be established that produce commensurate VOC emissions levels due to the variability of still design, throughput, and soil loadings. However, general parameters indicative of acceptable operating conditions will be delineated as a guideline to minimizing VOC emissions from still residue.

According to a still manufacturer, one of the principal influences on the solvent content of still residue is the frequency of still boildown.

Although many existing plants boil down their stills on a routine or convenient schedule, the still manufacturer recommends that boildown be undertaken only after the flow rate of condensed liquid (solvent and water) between the condenser and moisture separator has been reduced by approximately 75 percent (Washex, 1973). The duration of boildown should continue until the flow rate of condensed liquid has been again reduced by 75 percent, with the full available steam pressure of 390 kilopascals (100 psi) being used to evaporate solvent from the residue. Thus, the 75 percent condensate flow reduction criterium can be applied to both normal distillation operation and to the optimum duration of boildown.

Factors affecting the rate of distillation include the solvent boiling range, the level of solvent contamination, the quantity of residue in the still, and the steam pressure. Under a typical vacuum range of 42 kilopascals to 52 kilopascals (22 inches to 27 inches of mercury), petroleum solvents with flash points of 41°C, 52°C, and 60°C boil under recommended steam pressure ranges of 136 kilopascals to 234 kilopascals (35 to 60 psi), 195 kilopascals to 253 kilopascals (50 to 65 psi), and 292 kilopascals to 351 kilopascals (75 to 90 psi), respectively (Washex, 1973). However, these steam pressure ranges will increase significantly with an increase in the quantity of contaminants in the incoming solvent. The level of residue in the still boiling chamber may also necessitate higher steam pressures in order to overcome the poor heat transfer of the accumulated residue.

A still manufacturer lists the following typical operating parameters for satisfactory still operation (Washex, 1973):

Steam Supply = 390 kilopascals (100 psi)
Condenser Water Supply = 78 kilopascals @ 18°C (20 psi @ 65°F)
Condenser Water Outlet Temperature = 60°C to 71°C (140°F to 160°F)
Condenser Solvent Outlet Temperature = 24°C to 32°C (75°F to 90°F)

While these parameters will vary as a function of the given still, plant throughput, and soil loading, they nevertheless form a general range which may be indicative of proper still operation. They are even more effective when combined with the previously discussed guidelines on still boildown duration and procedures. Principal maintenance procedures are also outlined by the still manufacturer and include removal and cleaning of the steam coils after about 1000 hours of operation and frequent lubrication of the condensate pump (Washex, 1973).

The application of the previously discussed operating and maintenance recommendations could result in significant VOC emission reductions due to the resultant decrease in the solvent content of disposed still waste. However, no specific data are available on reductions in still waste solvent content as a function of the implementation of these procedures. Based on worst-case existing emissions of 1 to 7 kilograms VOC per 100 kilograms articles cleaned (Andrasik, 1981; Jernigan and Kezerle, 1981), improved operating and maintenance procedures could reduce these emission rates to as little as 1 to 3 kilograms VOC per 100 kilograms articles cleaned (Andrasik, 1981).

Solvent vapor losses from settling and storage tanks contribute significantly to overall fugitive emission. These emissions generally occur as a result of "breathing" and "working" losses. Breathing losses occur when the vapor volume in storage tanks expand or contract during changes in temperature. This results in air being drawn into the tank (vapor contraction) and solvent vapor being expelled to the atmosphere (vapor expansion). In contrast, working losses result from changes in the vented free volume above the stored liquid solvent. Solvent vapor is expelled when the tank is filled. Draining draws in atmospheric air, thereby producing additional breathing losses as the air becomes saturated with solvent vapor. In either case, steps should be taken to remove the solvent vapor from the expelled air and to prevent the tank contents from being exposed to the atmosphere.

Miscellaneous emissions essentially encompass all remaining emission sources. An EPA-sponsored test program conducted at a large industrial dry cleaning facility included a sampling and evaluation of VOC concentrations in the general dry cleaning environment (Jernigan and Kezerle, 1981). Significant concentrations of solvent vapor, at times approaching 70 percent of the solvent LEL, were found around both the settling tank and the new solvent tank vents. Another significant source of VOC emissions was the washer which produced concentrations nearing 10 percent of the solvent LEL in its immediate vicinity. Additional measurements of VOC concentrations in dry cleaning room roof exhaust vents yielded an estimated VOC emission rate of 0.5 kg solvent per 100 kg of articles cleaned (Jernigan and Kezerle, 1981).

The broad category of "leaks" can contribute significantly to overall plant fugitive VOC emissions. Liquid solvent drips from pipes, fittings, valves, hoses, couplings, and pumps add to te constant background of solvent vapor inherent to many dry cleaning plants. Vapor leaks from dryers, exhaust ducts, filter housings, stills, and open or improperly sealed containers of solvent and solvent-laden waste all contribute to the quantity of solvent emitted to the environment.

The only way to eliminate this general class of fugitive emissions is with an effective program of maintenance and training. A dry cleaning trade association has estimated that approximately 1.0 kg of VOC is emitted by fugitive sources for every 100 kg of articles cleaned in a typical dry cleaning plant (Fisher, 1975). This level of VOC emissions could be reduced by conducting a maintenance program that would completely eliminate liquid leaks and solvent standing open to the atmosphere and eradicate vapor leaks. Vapor leaks could be eradicated by repairing gaskets and seals that obviously expose solvent-rich environments to the atmosphere. Training of dry cleaning personnel could help in attaining this reduction, particularly by eliminating the practice of allowing solvent-laden loads of articles to be exposed to the atmosphere while awaiting drying. Equipment operators and maintenance personnel should be taught to inspect and identify solvent liquid and vapor leaks from sources such as hose and pipe connections, pumps, machine and tank gaskets, seals, valves, and lint and button traps. If leaks are found, repairs should be undertaken immediately with the goal of minimizing any additional solvent leakage.

4.4 REFERENCES FOR CHAPTER 4

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5. MODIFICATION AND RECONSTRUCTION

Standards of performance are applicable to those facilities listed in the standards whose construction, modification, or reconstruction commenced (as defined under 40 CFR 60.2(i)) after proposal of the standards. Such facilities are termed "affected facilities." Standards of performance are not applicable to facilities whose construction, modification, or reconstruction commenced on or before proposal of the standards. These facilities are referred to as "existing facilities." However, an existing facility may become an affected facility and therefore subject to standards, if the facility undergoes modification or reconstruction.

Modification and reconstruction are defined under 40 CFR 60.14 and 60.15, respectively. These general provisions are summarized in Section 5.1. Section 5.2 discusses the applicability of these provisions to process facilities in the petroleum solvent dry cleaning industry.

5.1 SUMMARY OF MODIFICATION AND RECONSTRUCTION PROVISIONS

5.1.1 Modification

With certain exceptions, any physical or operational change to an existing facility that would result in an increase in the emission rate to the atmosphere of any pollutant to which a standard applies, would be considered a modification within the meaning of Section 111 of the Clean Air Act. The key to a modification determination is whether total emissions to the atmosphere (expressed in kg/hr) from the facility as a whole have increased as a result of the change. For example, if the affected facility is defined as a group of pieces of eqipment, then the aggregate emissions from all the equipment must increase before the facility will be considered modified.

Exceptions which allow certain changes to an existing facility without it becoming an affected facility, irrespective of an increase in emissions, are listed below.

1. Routine maintenance, repair, and replacement.
2. An increase in production rate without a capital expenditure (as defined in 40 CFR 60.2(bb)).
3. An increase in the hours of operation.
4. Use of an alternative fuel or raw material if, prior to the standard, the existing facility was designed to accommodate that alternate fuel or raw material.
5. The addition or use of any system or device whose primary function is the reduction of air pollutants, except when an emission control system is removed or is replaced by a system determined by EPA to be less environmentally beneficial.
6. Relocation or change in ownership of the existing facility.

Once an existing facility is determined to be modified, all of the emission sources of that facility are subject to the standards of performance for the pollutant whose emission rate increased and not just the emission source which displayed the increase in emissions. However, a modification to one existing facility at a plant will not cause other existing facilities at the same plant to become subject to standards.

An owner or operator of an existing facility who is planning a physical or operational change which may increase the emission rate of a pollutant to which a standard applies shall notify the appropriate EPA regional office 60 days prior to the change, as specified in §60.7(a)(4).

5.1.2 Reconstruction

An existing facilty may also become subject to new source performance standards if it is "reconstructed." As defined in 40 CFR 60.15, a reconstruction is the replacement of the components of an existing facility to the extent that (1) the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost of a comparable new facility, and (2) it is technically and economically feasible for the facility to meet the applicable standards. Because EPA considers reconstructed facilities to constitute new construction rather than modification, reconstruction determinations are made irrespective of changes in emission rate.

The purpose of the reconstruction provisions is to discourage the perpetuation of an existing facility (instead of replacing it at the end of its useful life) for the sole purpose of circumventing a standard which is applicable to new facilities. Without such a provision all but vestigal components (such as frames, housing, and support structures) of the existing facility could be replaced without the facility being considered a "new" facility subject to new source performance standards. If the facility is determined to be reconstructed, all of the provisions of the standards of performance applicable to that facility must be complied with.

If an owner or operator of an existing facility is planning to replace components and the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost of a comparable new facility, the owner or operator shall notify the appropriate EPA regional office 60 days before the construction of the replacements commences.

5.2 PETROLEUM SOLVENT DRY CLEANING AFFECTED FACILITIES

In order to cover all significant sources of emissions from petroleum solvent dry cleaning plants, the affected facility will be defined as each of the primary VOC emitting pieces of equipment in a facility. This equipment comprises the following: dryers, washers, vacuum stills, solvent filtration systems, and settling tanks.

The modification and reconstruction provisions do not significantly impact the petroleum solvent dry cleaning industry. Facilities in this industry seldom reconstruct process equipment to the extent that the capital cost of the reconstruction exceeds 50 percent of the fixed capital cost which would be required to construct a comparable, entirely new facility. Additionally, no equipment changes or modifications are anticipated to occur that will increase VOC emissions.

6. MODEL PLANTS AND REGULATORY ALTERNATIVES

This chapter defines the model plants which have been selected to represent the petroleum solvent dry cleaning industry and the alternative means by which volatile organic compound emissions can be regulated.

6.1 MODEL PLANTS

Five model plants – small commercial, medium commercial, large commercial, small industrial, and large industrial – have been developed to represent the various configurations of equipment and throughput in the petroleum solvent dry cleaning industry. The model plants are based on information obtained from plant visits and surveys, as well as consultations with industry, trade association, and equipment manufacturing representatives (Fisher, 1980a; Fisher, 1980b; Sluizer, 1981; Marvel, et al, 1980). These five model plants will be used to estimate the environmental, energy, and economic impacts of the various emission control alternatives for the petroleum solvent dry cleaning industry. Petroleum solvent dry cleaning facilities have varying operating characteristics and equipment configurations that prevent explicit categorization of these facilities into specific model plant classifications. Also, the model plants are not distinctly indicative of the actual plant capacities that exist in the petroleum solvent dry cleaning industry. Consequently, the model plants were classified primarily by plant throughput and, in part, by the types of articles cleaned to simplify the representation of the range of sizes and types of dry cleaning plants.

Commercial petroleum solvent dry cleaning plants offer dry cleaning services to the general public and to institutional customers, primarily cleaning personal items such as suits, coats, dresses, and uniforms. Industrial petroleum solvent dry cleaning plants offer dry cleaning services primarily to industrial customers in conjunction with the rental of industrial items such as mops, shop towels, work gloves, and floor mats. The model plant parameters based on existing equipment are presented in Table 6-1 for the five model plants.

The small commercial model plant category presently comprises about 600 operating establishments nationwide or 10 percent of the aggregate commercial petroleum solvent dry cleaning industry (Fisher, 1980b). The average daily throughput for this model plant is approximately 56 kilograms of general apparel. The soil loading of the articles cleaned for this model plant category is relatively low, and the annual petroleum solvent consumption ranges from 3,000 to 6,800 liters. The small commercial model plant includes one washer, one standard dryer, one vacuum still, and 7 filter cartridges.

The medium commercial model plant category presently comprises 4,140 operating establishments nationwide or 67 percent of the aggregate commercial petroleum solvent dry cleaning industry (Fisher, 1980b). With an average daily throughput of approximately 128 kilograms of general apparel, this model plant is identical to the small model with the exception of the larger throughput capacity. As a result of this larger throughput, a larger volume of petroleum solvent, 6,800 to 15,600 liters per year, is consumed. This model plant includes one washer, one dryer, one vacuum still, and 10 filter cartridges.

The large commercial model plant category presently comprises 1,400 operating establishments nationwide or about 23 percent of the commercial petroleum solvent dry cleaning industry (Fisher, 1980b). These plants may have contracts to clean hospital uniforms or other types of uniforms in addition to general apparel. The average daily throughput is approximately 328 kilograms, or more than double the throughput capacity of the medium commercial model plant. The large commercial model plant consumes 17,300 to 40,100 liters of petroleum solvent annually and includes one washer, one dryer, one vacuum still, and 21 filter cartridges.

The small industrial model plant category presently comprises 60 operating establishments nationwide or 26 percent of the aggregate industrial petroleum solvent dry cleaning industry (Sluizer, 1981). The average daily throughput is approximately 700 kilograms of industrial

Table 6-1. MODEL PLANT PARAMETERS

Parameter	Model plants				
	Small commercial	Medium commercial	Large commercial	Small industrial	Large industrial
Number of existing plants nationwide in 1979	600	4,150	1,400	60	170
Annual plant solvent consumption liters (gallons)[b]	4,300 (1,100)	9,800 (2,600)	25,100 (6,600)	56,000 (14,700)	195,000 (52,000)
Annual plant throughput kg (lbs)	14,000 (31,000)	32,000 (70,000)	82,000 (180,000)	182,000 (400,000)	635,000 (1,400,000)
Normal operations (days/year)	250	250	250	260	260
Throughput description	General apparel	General apparel	General apparel	Industrial articles	Industrial articles
Number of washers	1	1	1	1	2
Washer capacity (each) kg (lbs)	16 (35)	23 (50)	45 (100)	115 (250)	225 (500)
Average washer load weight kg (lbs)	9 (20)	16 (35)	36 (80)	90 (200)	180 (400)
Number of washer loads per day	6	8	9	8	14
Wash cycle time, minutes	20	25	25	40	40
Number of dryers	1	1	1	3	2
Dryer capacity (each) kg (lbs)	23 (50)	23 (50)	45 (100)	45 (100)	180 (400)
Dry cycle time, minutes	25	30	30	40	40
Number of vacuum stills	1	1	1	1	3
Vacuum still capacity (each) L/hr (gal/hr)	100 (25)	200 (50)	400 (100)	1,900 (500)	1,900 (500)
Number of filter cartridges	7	10	21	63	N/A[a]
Number of settling tanks	N/A[a]	N/A[a]	N/A[a]	1	2
settling tank capacity (each) liters (gallons)				5,700 (1,500)	5,700 (1,500)

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[a] Not applicable.

[b] Based on nominal emission rate of 23 kg solvent/100 kg articles.

articles such as rental uniforms, rugs, mops, and mats. The small industrial model plant includes one washer, three dryers, one vacuum still, and 63 filter cartridges. However, some small industrial plants may omit solvent filtration, employing instead a solvent settling tank prior to distillation.

The large industrial model plant category presently comprises 170 operating establishments or about 74 percent of the nationwide industrial petroleum solvent dry cleaning industry (Sluizer, 1981). The large industrial model plant has an average daily throughput of approximately 2,442 kilograms of industrial articles such as rental uniforms, mops, rugs, and mats. These plants often operate with multiple shifts and require equipment with large capacities for almost continuous operation. This model plant includes two washers, two large capacity standard dryers, three vacuum stills, and two settling tanks. Typically, solvent filtration systems are not used by large industrial plants because of the excessive soil loading of the articles cleaned.

6.2 REGULATORY ALTERNATIVES

The purpose of this section is to define different regulatory alternatives based upon their effectiveness in reducing VOC emissions. The regulatory alternatives are based on the emission control techniques discussed in Chapter 4. The VOC emissions resulting from the application of the control technology mandated by each regulatory alternative are given in Table 6-2 for each model plant. Ranges are used to illustrate that significant variations in VOC emission rates can occur due to variations in operating procedures.

Alternative I requires no additional regulatory action other than what presently exists for the industry. This alternative is representative of the equipment and emission levels that would exist without any additional control requirements. Under this alternative, standard dryers emit solvent vapors directly to the atmosphere, cartridge filters are in general use for solvent filtration without specific drainage periods, and VOC emissions from fugitive sources such as disposed vacuum still and settling tank wastes, as well as general vapor and liquid leaks, are uncontrolled.

Table 6-2. MODEL PLANT EMISSION RATES FOR REGULATORY ALTERNATIVE I, II, AND III (emission rates in kilograms of VOC emitted per 100 kilograms of articles cleaned)

					General fugitive emissions		
Regulatory alternative	**Model[e] plant**	**Standard dryer**	**Recovery dryer**	**Cartridge filter**	**Vacuum still**	**Miscellaneous fugitive**	**Total**
	SC	14-28 (18)[a]	b	0.5-1 (1)	1-7 (3)	0.5-1 (1)	16-37 (23)
	MC	14-28 (18)	b	0.5-1 (1)	1-7 (3)	0.5-1 (1)	16-37 (23)
I	LC	14-28 (18)	b	0.5-1 (1)	1-7 (3)	0.5-1 (1)	16-37 (23)
	SI	14-28 (18)	b	0.5-1 (1)	1-7 (3)	0.5-1 (1)	16-37 (22)[d], (23)
	LI	14-28 (18)	b	c	1-7 (3)	0.5-1 (1)	15.5-36 (22)
	SC	14-28 (18)	b	0.5-1 (1)	1-7 (3)	0.5-1 (1)	16-37 (23)
	MC	14-28 (18)	b	0.5-1 (1)	1-7 (3)	0.5-1 (1)	16-37 (23)
II	LC	14-28 (18)	b	0.5-1 (1)	1-7 (3)	0.5-1 (1)	16-37 (23)
	SI	14-28 (18)	b	0.5-1 (1)	1-7 (3)	0.5-1 (1)	16-37 (22)[d], (23)
	LI	14-28 (18)	b	c	1-7 (3)	0.5-1 (1)	15.5-37 (22)
	SC	b	0.7-9.5 (3.5)	0.5-1 (1)	1-7 (3)	0.5-1 (1)	2.7-18.5 (8.5)
	MC	b	0.7-9.5 (3.5)	0.5-1 (1)	1-7 (3)	0.5-1 (1)	2.7-18.5 (8.5)
III	LC	b	0.7-9.5 (3.5)	0.5-1 (1)	1-7 (3)	0.5-1 (1)	2.7-18.5 (8.5)
	SI	b	0.7-9.5 (3.5)	0.5-1 (1)	1-7 (3)	0.5-1 (1)	2.7-18.5 (7.5)[d], (8.5)
	LI	b	0.7-9.5 (3.5)	c	1-7 (3)	0.5-1 (1)	2.2-17.5 (7.5)

[a] Numbers in parentheses are nominal values representing an overall emission rate (either an average of test data or a value widely accepted in the industry).

[b] Not applicable.

[c] Large industrial plants normally omit filtration.

[d] Small industrial plants sometimes omit filtration with heavy soil loading.

[e] SC = small commercial.
MC = medium commercial.
LC = large commercial.
SI = small industrial.
LI = large industrial.

Alternative II would reduce overall VOC emissions from dry cleaning plants by means of an effective maintenance program which would eliminate perceptable fugitive leaks, and would minimize cartridge filter emissions with a minimum drain time of 8 hours for used cartridge filters prior to disposal. This alternative would result in no specific emission reductions beyond baseline emission because reductions due to leak repair and cartridge drainage have not been quantified. The nominal emission rate for commercial model plants and small industrial model plants employing filtration would be 23 kilograms (ranging from 16 to 37 kilograms) VOC per 100 kilograms of articles cleaned under Alternative II. The nominal emission rate for industrial model plants omitting filtration would be 22 kilograms (ranging from 15.5 to 37 kilograms) VOC per 100 kilograms of articles cleaned under Alternative II.

Alternative III mandates the use of a recovery dryer instead of the standard dryer in addition to the filtration and fugitive emission control provisions of Alternative II, making this the most stringent alternative. The nominal emission rate is 8.5 kilograms (ranging from 2.7 to 18.5 kilograms) VOC per 100 kilograms articles cleaned for all model plants with the exception of the small (omiting filtration) and large industrial plant, which have a nominal emission rate of 7.5 kilograms (ranging from 2.2 to 17.5 kilograms) VOC per 100 kilograms articles cleaned. Alternative III produces a nominal VOC emission rate decrease of about 14.5 kilograms (ranging from 13.3 to 18.5 kilograms) VOC per 100 kilograms articles cleaned relative to baseline emission levels.

6.3 REFERENCES FOR CHAPTER 6

Fisher, W. 1980a. International Fabricare Institute (IFI) Meeting with S. Plaisance, TRW Inc., December 9. Number of cartridge filters in use.

Fisher, W. 1980b. IFI, Telecon with Q. Corey, TRW Inc., January 16. Comments on the size of the commercial petroleum dry cleaning industry and the throughput from a typical plant.

Marvel Manufacturing Co., Washex Machinery, Inc., American Laundry Machinery, W.M. Cissel Manufacturing Co., VIC Manufacturing Co. and Challenge-Cook Brothers, Inc. 1980. Telecon Survey with Q. Corey, TRW Inc., March 18-April 25. Sizes of petroleum dry cleaning equipment and expected sales for 1980.

Sluizer, M. 1981. IIL, Telecon with S. Plaisance, TRW Inc., April 10. Size of the industrial petroleum dry cleaning industry and the throughput of a typical plant.

7. ENVIRONMENTAL IMPACTS

The environmental and energy impacts associated with the implementation of each Regulatory Alternative (presented in Chapter 6) are discussed in this chapter with respect to air quality, water quality, solid waste, and energy consumption. Both beneficial and adverse impacts are assessed.

7.1 AIR IMPACTS

Annual VOC emissions and emission reductions in the five model plants under the three Regulatory Alternatives are illustrated in Table 7-1. The model plant emission rates for each Regulatory Alternative are developed in Chapter 6, and are multiplied by the model plant annual throughput to derive the model plant annual VOC emissions. Ranges are used to illustrate that significant variations in VOC emission rates can occur due to variations in operating procedures. Alternative I (baseline) emissions are proportional to plant throughputs, with the small commercial model plant having the lowest annual emission range (2.2 to 5.2 megagrams VOC per year) and the large industrial model plant having the highest range (98.4 to 229 megagrams VOC per year). Because Alternative II emission reductions resulting from fugitive emission control are not quantifiable, the Alternative II emission rates remain unchanged from those given under Alternative I in Table 7-1. Under Alternative III, model plant annual emissions range from a low in the small commercial plant of 0.4 to 2.6 megagrams VOC per year to a maximum of 14.0 to 111 megagrams VOC per year in the large industrial plant. Emission reductions resulting from the implementation of Alternative III are also listed in Table 7-1 and are proportional to the model plant throughputs. The incremental annual emission reductions of Alternative III over Alternative I range from a minimum of 1.8 to 2.6 megagrams VOC per year in the small commercial plant to a maximum of 84.4 to 118 megagrams VOC per year in the large industrial model plant.

Table 7-1. ANNUAL VOC EMISSION IMPACTS OF THE THREE REGULATORY ALTERNATIVES IN THE FIVE MODEL PLANTS

Model plant (throughput in Kg/yr)	Annual VOC emissions in Mg VOC/yr			VOC emission reduction from baseline (Alternative I) in Mg VOC/yr	
	I	II	III	II	III
Small commercial (14,000)	2.2 - 5.2	2.2 - 5.2	0.4 - 2.6	[a]	1.8 - 2.6
Medium commercial (32,000)	5.1 - 11.8	5.1 - 11.8	0.9 - 5.9	[a]	4.2 - 5.9
Large commercial (82,000)	13.1 - 30.3	13.1 - 30.3	2.2 - 15.2	[a]	10.9 - 15.2
Small industrial (182,000)	28.2 - 67.3	28.2 - 67.3	4.9 - 33.7	[a]	24.2 - 33.7
Large industrial (635,000)	98.4 -228.6	98.4 -228.6	14.0 -111.1	[a]	84.5 -117.5

[a] Regulatory Alternative II emission reductions resulting from fugitive emission controls are not quantifiable.

Cumulative nationwide VOC emissions associated with each regulatory alternative were derived by multiplying the cumulative number of affected model plants existing through each year by the appropriate model plant VOC emissions. The projected cumulative number of model plants is presented in Table 7-2, and the annual VOC emissions were obtained from Table 7-1. Cumulative nationwide emissions are presented in Table 7-3 for each model plant category for the ten years following proposal of the standards. Ranges are used to illustrate that significant variations in VOC emission rates can occur due to variations in operating parameters. Because of the larger number of plants, the commercial model plant category produces a larger quantity of nationwide VOC emissions than the industrial model plant category. The medium commercial model plant category is the most numerous category, and contributes the largest total quantity of VOC emissions in the commercial sector. Nationwide ten-year emissions from the medium commercial model plant category decrease from a range of 38,700 to 89,600 megagrams VOC per year under Alternative I to a range of 6,800 to 44,800 megagrams VOC per year under Alternative III. The largest single source of VOC emissions, however, is the large industrial model plant category. This category produces the highest nationwide ten-year emissions (43,300 to 101,000 megagrams VOC pear year under Alternative I and 6,200 to 48,800 megagrams VOC per year under Alternative III). These high emission levels result from the large throughput capacity of this category. The smallest single source of VOC emissions is the small commercial model plant category, due to the relatively limited number of plants and low throughput capacity. The small commercial model plant category has ten-year nationwide emissions of 2,400 to 5,700 megagrams VOC per year under Alternative I and from 400 to 2,900 megagrams VOC per year under Alternative III. Total nationwide emissions are at a maximum under Regulatory Alternative I (123,000 to 286,000 megagrams VOC per year) and are lowest under Regulatory Alternative III (19,900 to 141,000 megagrams VOC per year). This difference is expected because Alternative I requires no additional controls above baseline while Alternative III requires the most effective emission controls.

Table 7-2. PROJECTED NUMBER OF AFFECTED PLANTS OVER TEN YEARS FOLLOWING PROPOSAL OF THE STANDARDS

		Small commercial	Medium commercial	Large commercial	Small industrial[b]	Large industrial[c]
Total number of existing plants nationwide in:	1979	600	4,150	1,400	60	170
	1980	600	4,150	1,400	61	172
	1981	600	4,150	1,400	61	173
Additional number of affected plants nationwide in:	1982	20	138	47	2.6	7.5
	1983	20	138	47	2.7	7.5
	1984	20	138	47	2.7	7.6
	1985	20	138	47	2.7	7.7
	1986	20	138	47	2.7	7.8
	1987	20	138	47	2.8	7.8
	1988	20	138	47	2.8	7.9
	1989	20	138	47	2.8	8.0
	1990	20	138	47	2.8	8.1
	1991	20	138	47	2.9	8.2
	1992	20	138	47	2.9	8.2

[a] Based on zero growth rate in commercial plants, 1 percent growth rate in industrial plants, and an expected equipment life of 30 years for dryers and vacuum stills.

[b] The average number of additional affected plants per year is approximately 3.

[c] The average number of additional affected plants per year is approximately 8.

Table 7-3. CUMULATIVE NATIONWIDE VOC IMPACTS OF THE FIVE MODEL PLANTS UNDER THREE REGULATORY ALTERNATIVES FOR TEN YEARS

Model plant category	Year	Cumulative nationwide emissions through each year, Mg VOC			Cumulative nationwide emission reduction through each year under Regulatory Alternative III, Mg/VOC
		Alternative I	Alternative II[a]	Alternative III	
Small commercial	1	44-104	44-104	8-52	36-52
	2	132-312	132-312	24-156	108-156
	3	264-624	264-624	48-312	216-312
	4	440-1,040	440-1,040	80-520	360-520
	5	660-1,560	660-1,560	120-780	540-780
	6	924-2,180	924-2,180	168-1,090	756-1,090
	7	1,232-2,910	1,232-2,910	224-1,460	1,010-1,450
	8	1,580-3,740	1,580-3,740	288-1,870	1,290-1,870
	9	1,980-4,680	1,980-4,680	360-2,340	1,620-2,340
	10	2,420-5,720	2,420-5,720	440-2,860	1,980-2,860
Medium commercial	1	704-1,630	704-1,630	124-814	580-816
	2	2,110-4,890	2,110-4,890	373-2,440	1,740-2,450
	3	4,220-9,770	4,220-9,770	745-4,890	3,480-4,880
	4	7,040-16,300	7,040-16,300	1,240-8,140	5,800-8,160
	5	10,600-24,400	10,600-24,400	1,860-12,200	8,740-12,200
	6	14,800-34,200	14,800-34,200	2,610-17,100	12,200-17,100
	7	19,700-45,600	19,700-45,600	3,480-22,800	16,200-22,800
	8	25,300-58,600	25,300-58,600	4,470-29,300	20,800-29,300
	9	31,700-73,300	31,700-73,300	5,590-36,600	26,100-36,700
	10	38,700-89,600	38,700-89,600	6,830-44,800	31,900-44,800
Large commercial	1	616-1,420	616,1,420	103-714	513-706
	2	1,850-4,270	1,850-4,270	310-2,140	1,540-2,130
	3	3,690-8,540	3,690-8,540	620-4,290	3,070-4,250
	4	6,160-14,200	6,160-14,200	1,030-7,140	5,130-7,060
	5	9,240-21,400	9,240-21,400	1,550-10,700	7,690-10,700
	6	12,900-29,900	12,900-29,900	2,170-15,000	10,730-14,900
	7	17,200-39,900	17,200-39,900	2,900-20,000	14,300-19,900
	8	22,200-51,300	22,200-51,300	3,720-25,700	18,500-25,600
	9	27,700-64,100	27,700-64,100	4,650-32,100	23,100-32,000
	10	33,900-78,300	33,900-78,300	5,690-39,300	28,200-39,000
Small industrial	1	85-202	85-202	15-101	70-101
	2	254-606	254-606	44-303	210-303
	3	508-1,210	508-1,210	88-607	420-603
	4	846-2,020	846-2,020	147-1,010	699-1,010
	5	1,270-3,030	1,270-3,030	221-1,520	1,050-1,510
	6	1,780-4,240	1,780-4,240	309-2,120	1,470-2,120
	7	2,370-5,650	2,370-5,650	412-2,830	1,960-2,820
	8	3,050-7,270	3,050-7,270	529-3,640	2,520-3,630
	9	3,810-9,090	3,810-9,090	662-4,550	3,150-4,540
	10	4,650-11,100	4,650-11,100	809-5,560	3,840-5,540
Large industrial	1	787-1,830	787-1,830	112-888	675-942
	2	2,360-5,500	2,360-5,500	336-2,660	2,020-2,840
	3	4,720-11,000	4,720-11,000	672-5,330	4,050-5,670
	4	7,870-18,300	7,870-18,300	1,120-8,880	6,750-9,420
	5	11,800-27,500	11,800-27,500	1,680-13,300	10,100-14,200
	6	16,500-38,500	16,500-38,500	2,350-18,600	14,200-19,900
	7	22,000-51,300	22,000-51,300	3,140-24,900	18,900-26,400
	8	28,300-66,000	28,300-66,000	4,030-32,000	24,300-34,000
	9	35,400-82,400	35,400-82,400	5,040-40,000	30,400-42,400
	10	43,300-101,000	43,300-101,000	6,160-48,800	37,100-52,200
Total industry	1	2,240-5,190	2,240-5,190	362-2,570	1,880-2,620
	2	6,710-15,600	6,710-15,600	1,080-7,690	5,630-7,910
	3	13,400-31,100	13,400-31,100	2,160-15,400	11,200-15,700
	4	22,400-51,900	22,400-51,900	3,620-25,700	18,800-26,200
	5	33,600-77,900	33,600-77,900	5,420-38,500	28,200-39,400
	6	46,900-109,000	46,900-109,000	7,640-53,900	39,300-55,100
	7	62,500-145,000	62,500-145,000	10,200-72,000	52,300-73,000
	8	80,400-187,000	80,400-187,000	13,100-92,800	67,300-94,200
	9	101,000-234,000	101,000-234,000	16,300-116,000	84,700-118,000
	10	123,000-286,000	123,000-286,000	19,900-141,000	103,000-145,000

[a] Regulatory Atlernative II emission reductions resulting from fugitive emission controls are not quantifiable.

The nationwide VOC emission reductions associated with Regulatory Alternative III for each model plant category are also presented in Table 7-3 for the ten-year period following proposal of the standards. These emission reductions were derived by subtracting the given Regulatory Alternative emissions from the baseline emissions in Table 7-3. Alternative I is representative of the existing baseline and therefore, results in no emission reduction. Regulatory Alternative II emission reductions resulting from fugitive emission control are not quantifiable and are consequently, not presented.

The largest potential for total ten-year VOC emission reduction in the commercial sector is in the medium commercial model plant category which has reductions ranging from 31,900 to 44,800 megagrams VOC per year. The large industrial model plant category with reductions ranging from 37,100 to 52,200 megagrams VOC per year, has the largest total ten-year VOC emissions reduction relative to the other four model plant categories. Th small commercial model plant category with reductions of 1,980 to 2,860 megagrams VOC per year, has the least total ten-year VOC emissions reduction. The large Regulatory Alternative III emission reduction results primarily from the requirement of replacing standard dryers with recovery dryers. Alternative III results in a 50 to 85 percent emission reduction from baseline depending on the operating parameters of the plant.

7.2 WATER IMPACTS

Water pollution impacts in petroleum solvent dry cleaning plants result from the production of wastewater that may contain residual solvent. This wastewater is produced by sources such as recovery dryers and vacuum stills. The disposal of solvent-laden cartridge filter elements in landfills could increase the quantity of VOC in groundwater (see Chapter 4). However, cartridge filtration is assumed to be the predominant form of filtration in the industry and, as such, is unaffected under the three Regulatory Alternatives developed in Chapter 6. Even though the quantity of solvent in disposed still waste is reduced through improved operation and maintenance procedures under Regulatory Alternatives II and III, water pollution resulting from incomplete separation of solvent and water in the vacuum still is assumed to be unaffected.

The primary source of VOC water pollution resulting from implementation of emission controls is the recovery dryer (see Chapter 4). In this unit, the condensed mixture of solvent and water is separated by a gravimetric separator. In the gravimetric separator the difference in the densities of solvent (0.75 kilograms/liter) and water (1.0 kilograms/liter) provides the basis for separation. In an EPA field test of a recovery dryer, the most recent and complete test data indicate that the unit recovered an average of approximately 3.29 kilograms of water per 100 kilograms of articles cleaned (Plaisance et al., 1981). The separator on the domestically manufactured recovery dryer is designed such that the unit must be level in order to prevent solvent from entering the stream of recovered water. If the separator housing is not level, the recovered water that is typically disposed in a public sewer will contain additional petroleum solvent.

If the recovery dryer gravimetric separator is properly installed and maintained, the quantity of solvent contained in the sewered water would be limited to that which is dissolved in the recovered water. A representative of a petroleum solvent manufacturer has estimated the maximum solubility of petroleum solvent in water as 100 parts per million by volume (ppmv) (Saary, 1981). This value is combined with the previous estimate of water recovery as a function of cleaning throughput to form the basis for the determination of the mass of solvent contained in sewered water.

Annual water pollution impacts in the five model plants are listed in Table 7-4, based on the previously discussed assumption that these impacts will only result from the recovery dryers required under Regulatory Alternative III. The quantity of petroleum solvent contained in the sewered wastewater from the recovery dryer is insignificant in comparison to the total annual quantity of solvent-laden wastewater disposed. Furthermore, both the quantity of solvent itself and the solvent-laden wastewater disposed is a function of the model plant throughput. The solvent-laden wastewater and pure solvent sewered increase with throughput from the small commercial plant to the large industrial plant. The

Table 7-4. ANNUAL WATER POLLUTION IMPACTS OF EMISSION CONTROL IN FIVE MODEL PLANTS[a]

Model plant (throughput in Kg/yr)	Annual increase in mass of solvent-laden wastewater disposed in sewer (Mg/yr)	Annual increase in solvent in disposed wastewater (Kg/yr)
Small commercial (14,000)	0.46	0.03
Medium commercial (32,000)	1.05	0.08
Large commercial (82,000)	2.70	0.20
Small industrial (182,000)	5.98	0.45
Large industrial (635,000)	20.9	1.57

[a] Water impacts due to installation of recovery dryers under Regulatory Alternative III relative to Regulatory Alternative I.

small commercial plant sewers 0.5 megagrams per year of wastewater and 0.03 kilograms of pure solvent, while the large industrial plant sewers 21 megagrams of wastewater and 1.6 kilograms of pure solvent.

Table 7-5 illustrates the cumulative nationwide water pollution impacts due to the application of recovery dryers under Regulatory Alternative III. (As previously stated, Regulatory Alternatives I and II increase neither the quantity nor the solvent content of sewered water.) These were derived by multiplying the annual water impacts for each individual model plant, given in Table 7-4, by the appropriate cumulative number of affected plants projected to be existing through each year. The increased mass of solvent-laden water is based on the previous estimate of the recovery dryer water recovery rate. The increase in the mass of solvent in sewered water is based on the estimated maximum solubility of solvent in water. As can be seen in the table, the solvent in disposed wastewater is insignificant in comparison to the total sewered water even at the increased levels. Because of the lower annual throughput of articles cleaned, the small commercial model plant category has the lowest total water impacts for the ten-year period after proposal of the standards. The small commercial model plant category has a cumulative mass of sewered solvent-laden water of 510 megagrams and a cumulative mass of sewered solvent for the same period of 33.0 kilograms. In contrast, the greatest water pollution impacts occur in the large industrial model plant category. The cumulative mass of solvent-laden water for the large industrial plant category is 9,200 megagrams over ten years with a cumulative mass of sewered solvent for the same period of 690 kilograms. Nationwide water pollution impacts for the ten-year period increase from 470 megagrams to 25,700 megagrams in the mass of solvent-laden water disposed, with a corresponding increase from 35 kilograms to 1,900 kilograms in the mass of solvent disposed in the wastewater. Thus, while the implementation of Regulatory Alternative III would increase the projected mass of sewered water nationwide by as much as 25,700 megagrams, the actual nationwide total increase in the mass of solvent disposed in public sewers would be only 1,900 kilograms over ten years.

Table 7-5. CUMULATIVE NATIONWIDE WATER IMPACTS OF EMISSION CONTROL IN FIVE MODEL PLANT CATEGORIES UNDER REGULATORY ALTERNATIVE III FOR TEN YEARS

Model plant	Year	Cumulative increase in mass of solvent-laden wastewater (Mg)	Cumulative increase in solvent in disposed wastewater (Kg)
Small commercial	1	9.20	0.60
	2	27.6	1.80
	3	55.2	3.60
	4	92.0	6.00
	5	138	9.00
	6	193	12.6
	7	258	16.8
	8	331	21.6
	9	414	27.0
	10	506	33.0
Medium commercial	1	145	11.0
	2	435	33.1
	3	869	66.2
	4	1,450	110
	5	2,170	166
	6	3,040	232
	7	4,060	309
	8	5,220	397
	9	6,520	497
	10	7,970	607
Large commercial	1	127	9.40
	2	381	28.2
	3	761	56.4
	4	1,270	94.0
	5	1,900	141
	6	2,660	197
	7	3,550	263
	8	4,570	338
	9	5,710	423
	10	6,980	517
Small industrial	1	17.9	1.35
	2	53.8	4.05
	3	108	8.10
	4	179	13.5
	5	269	20.3
	6	377	28.4
	7	502	37.8
	8	646	48.6
	9	807	60.8
	10	987	74.3
Large industrial	1	167	12.6
	2	502	37.7
	3	1,000	75.4
	4	1,670	126
	5	2,510	188
	6	3,510	264
	7	4,680	352
	8	6,020	452
	9	7,520	365
	10	9,200	691
Total industry	1	466	35.0
	2	1,400	105
	3	2,790	210
	4	4,660	350
	5	6,990	524
	6	9,780	800
	7	13,000	979
	8	16,800	1,260
	9	20,900	1,570
	10	25,700	1,920

[a] Water impacts due only to installation of recovery dryers under Regulatory Alternative III.

7.3 SOLID WASTE IMPACTS

Solid waste emissions in petroleum dry cleaning plants result from the disposal of used cartridge filter elements and vacuum still residue. It is expected that total industry wide solid waste emissions will be reduced by the implementation of operating and maintenance procedures. However, for comparison purposes, it is assumed that solid waste emissions would be equivalent under the three alternatives because the solid waste emission reductions beyond the Alternative I baseline resulting from operating and maintenance procedures are unquantifiable. Consequently, a comparison of solid waste emission levels under the three alternatives is omitted.

7.4 ENERGY IMPACTS

Although petroleum dry cleaning plants include a wide range of equipment that consume electricity, steam, and fuel (oil, natural gas, or coal), the energy impacts include only those associated with the use of a standard dryer under Alternatives I and II and a recovery dryer and refrigerated chiller under Alternative III. Energy impacts associated with the implementation of operating and maintenance procedures are not quantifiable. Both standard (non-recovery) dryers and recovery dryers consume steam and electricity, with standard dryer consumption rates being significantly higher than those of recovery dryers (see Chapter 8 for consumption rates). The standard dryer consumes more energy because it has a larger fan and a resulting greater air flow which requires more steam for heating.

Annual energy impacts of the three regulatory alternatives for the five model plants are given in Table 7-6. Dryer energy consumption is determined by converting the energy costs (see Tables 8-9 through 8-13) of both steam and electricity into common units of work (gigajoules). The conversion factors used to convert steam and electricity costs per year ($/year) to units of work per year (gigajoules per year) are $6.37 per gigajoule and $16.67 per gigajoule, respectively (Vatavuk, 1980). As in the previously discussed environmental impacts, the overall consumption of energy increases proportionally with increased model plant throughput. The largest annual energy consumption would be produced by the large

Table 7-6. ANNUAL ENERGY IMPACTS OF THREE REGULATORY ALTERNATIVES IN FIVE MODEL PLANTS[a]

Model plant (throughput in Kg/yr)	Annual energy consumption in GJ/yr			Energy consumption reduction in GJ/yr	
	Alternative I	Alternative II	Alternative III	Alternative II	Alternative III
Small commercial (14,000)	48.5	48.5	31.8	0	16.7
Medium commercial (32,000)	127	127	81.5	0	45.5
Large commercial (82,000)	429	429	178	0	251
Small industrial (182,000)	1,250	1,250	485	0	765
Large industrial (635,000)	4,620	4,620	1,710	0	2,910

[a] Energy consumption is the sum of electrical and steam consumption, and include only that consumed by dryers and refrigerated chillers.

industrial model plant due to the relatively large throughput capacity of this category. The large industrial model plant consumes 4,600 gigajoules per year of energy under Alternative I and II and 1,700 gigajoules per year under Alternative III. An energy consumption reduction of 2,900 gigajoules per year in the large industrial model plant results from the implementation of Alternative III relative to Alternative I. The small commercial model plant which would be the smallest consumer of energy of the five model plants, consumes about 49 gigajoules per year under Alternative I and II and about 32 gigajoules per year under Alternative III. An energy consumption reduction of about 17 gigajoules per year in the small commercial model plant results from the implementation of Alternative III relative to Alternative I.

Cumulative nationwide energy impacts in the five model plant categories due to the three alternatives are presented in Table 7-7 for the ten years following proposal of the standards. The cumulative nationwide energy impacts were derived by multiplying the individual model plant energy consumptions given in Table 7-6 by the appropriate cumulative number of affected plants existing through each year given in Table 7-2. The large industrial model plant category consumes the largest ten-year cumulative nationwide amount of energy (2,030,000 gigajoules under Alternative I and 752,000 gigajoules under Alternative III). Consequently, the largest cumulative ten-year energy consumption reduction (1,280,000 gigajoules) occurs in the large industrial model plant category due to the implementation of Alternative III. The small commercial model plant category consumes the smallest ten-year cumulative nationwide amount of energy (53,400 gigajoules under Alternative I and II and 35,000 gigajoules under Alternative III). Consequently, the smallest cumulative ten-year energy consumption (18,400 gigajoules) occurs in the small industrial model plant category. The cumulative ten-year nationwide energy consumption for the total industry is 4,370,000 gigajoules under Alternative I and II and 1,950,000 gigajoules under Alternative III. Alternative III produces a cumulative nationwide ten-year energy consumption reduction of 2,420,000 gigajoules in the aggregate industry.

Table 7-7. CUMULATIVE NATIONWIDE ENERGY IMPACTS IN FIVE MODEL PLANTS UNDER THREE REGULATORY ALTERNATIVES FOR TEN YEARS

Model plant category	Year	Cumulative nationwide energy consumption (GJ)			Cumulative nationwide energy reduction due to Alternative III, (GJ)
		Alternative I	Alternative II[a]	Alternative III	
Small commercial	1	970	970	636	334
	2	2910	2910	1910	1000
	3	5820	5820	3820	2000
	4	9700	9700	6360	3340
	5	14600	14600	9540	5010
	6	20400	20400	13400	7010
	7	27200	27200	17800	9350
	8	34900	34900	22900	12000
	9	43700	43700	28600	15000
	10	53400	53400	35000	18400
Medium commercial	1	17500	17500	11300	5280
	2	52600	52600	33700	18800
	3	105000	105000	67500	37700
	4	175000	175000	113000	62800
	5	263000	263000	169000	94200
	6	368000	368000	236000	132000
	7	491000	491000	315000	176000
	8	631000	631000	405000	226000
	9	789000	789000	506000	283000
	10	964000	964000	619000	345000
Large commercial	1	20200	20200	8370	11800
	2	60500	60500	25100	35400
	3	121000	121000	50200	70800
	4	202000	202000	83700	118000
	5	303000	303000	126000	177000
	6	423000	423000	176000	248000
	7	565000	565000	234000	330000
	8	726000	726000	301000	425000
	9	907000	907000	377000	531000
	10	1110000	1110000	460000	649000
Small industrial	1	3750	3750	1460	2300
	2	11300	11300	4370	6890
	3	22500	22500	8730	13800
	4	37500	37500	14600	23000
	5	56300	56300	21800	34400
	6	78800	78800	30600	48200
	7	105000	105000	40700	64300
	8	135000	135000	52400	82600
	9	169000	169000	65500	103000
	10	206000	206000	80000	126000
Large industrial	1	37000	37000	13700	23300
	2	111000	111000	41000	69800
	3	222000	222000	82100	140000
	4	370000	370000	137000	233000
	5	554000	554000	205000	349000
	6	776000	776000	287000	489000
	7	1040000	1040000	383000	652000
	8	1340000	1340000	494000	841000
	9	1660000	1660000	616000	1050000
	10	2030000	2030000	752000	1280000
Total industry	1	79400	79400	35400	44000
	2	238000	238000	106000	132000
	3	476000	476000	212000	264000
	4	794000	794000	354000	440000
	5	1190000	1190000	531000	660000
	6	1670000	1670000	743000	924000
	7	2220000	2220000	991000	1230000
	8	2860000	2860000	1280000	1590000
	9	3570000	3570000	1590000	1980000
	10	4370000	4370000	1950000	2420000

[a] Regulatory Alternative II produces no quantifiable changes in energy consumption.

7.5 REFERENCES FOR CHAPTER 7

Plaisance, S., J. Jernigan, G. May, and C. Chatlynne. 1981. TRW Inc. Evaluation of Petroleum Solvent Concentrations, Emissions, and Recovery in a Solvent Recovery Dryer (EPA Contract No. 68-03-2560, Task No. T5013). February. [Rhode Island].

Saary, Z. 1981. Chevron Research Laboratory, Telecon with S. Plaisance, TRW Inc., July 20. Maximum solubility of Chevron petroleum solvent in water.

Vatavuk, W. 1980. Factors for Developing CTG Costs. Cost and Energy Analysis Section, Economic Analysis Branch. EPA/OAQPS. Research Triangle Park, North Carolina (Draft Document).

8. COST ANALYSIS

The cost impacts of implementing the three regulatory alternatives in the five model plants are discussed in this chapter. Although both process and control costs are presented for new model plants as well as any control costs resulting from the replacement of affected facilities, the emphasis is on the incremental control costs above the baseline regulatory alternative. Nationwide capital costs, annualized costs, and cost effectiveness of controls associated with each regulatory alternative are also presented for the industry and are projected for ten years following the proposal of the Standards.

8.1 BASIS FOR CAPITAL COSTS

Estimated capital costs for the implementation of each regulatory alternative are based on equipment suppliers' prices, as well as on EPA cost factors for taxes, freight, instrumentation, and installation (Vatavuk, 1980). All cost estimates are based on First Quarter 1981 prices and the worst case assumption that new dry cleaning equipment is required for each regulatory alternative.

Equipment costs are taken from manufacturers or equipment suppliers and include all major equipment necessary for compliance with each regulatory alternative (see Table 8-1 for a summary of existing and required control equipment costs). Cooling water for recovery dryer condensers can be supplied by cooling towers, refrigerated chillers, or from the existing process water system. The costs associated with each of these sources are given for each model plant size. However, in order to compare worst-case cost impacts, it is assumed that recovery dryers will require refrigerated chillers to supply adequate cooling water.

Taxes, freight, and instrumentation are lumped together as 18 percent of the equipment costs (Vatavuk, 1980). While this factor may be excessive for a simple, unitized device such as a recovery dryer, variations in

Table 8-1. AFFECTED EQUIPMENT COSTS IN FIVE MODEL PLANTS
(costs in thousands of first quarter 1981 dollars)

Equipment	Small commercial	Medium commercial	Large commercial	Small industrial	Large industrial
Existing Equipment					
Standard dryer	3.07[a]	3.07[a]	5.13[a]	15.39[a]	68.00[b]
Cartridge filter	1.30[a]	1.80[a]	3.90[a]	11.70[a]	N/A
Control Equipment					
Recovery dryer	15.64[c]	15.64[c]	16.18[c]	48.54[c]	129.44[c]
Cooling tower	1.35[d]	1.35[d]	1.35[d]	4.05[e]	10.80[e]
Refrig. chiller	2.30[f]	2.30[f]	2.55[f]	4.51[f]	11.50[f]

[a] Kirk, 1981.

[b] Miklas, 1981.

[c] Oakes, 1981.

[d] Hayworth, 1981.

[e] Adams, 1981.

[f] Chaffee, 1982.

NA - Not applicable.

shipping distance, method of transportation, and local taxes could increase this portion of the capital costs beyond this percentage.

Installation costs are estimated on the basis that all control equipment and process equipment in a new plant will be installed by an outside contractor at 10 percent of the equipment cost. Control equipment in an existing plant will be installed by maintenance personnel at 7.5 percent of the equipment costs (Bunyard, 1980). The installation of dryers, cooling towers, and refrigerated chillers is considered to be a simple maintenance procedure involving standard connections for electricity, steam, water and solvent flow lines. Minimal on-site assembly of equipment is expected.

Tables 8-2 through 8-6 give the capital costs for typical process equipment and subsystems contained in a dry cleaning plant, plus the floor space requirement for each model plant (Kirk, 1981). It is assumed that the cost to construct each of the model plants is $270 per square meter ($25 per square foot) plus $12.00 per square meter ($1.10 per square foot) for parking and loading facilities (McIver, 1981). While total capital costs for each new model plant increase from $58,000 for a small commercial model plant to $538,000 for a large industrial model plant, capital costs per kilogram of annual throughput decrease from $4.16/Kg in a new small commercial plant to $0.85/Kg of annual throughput in a large industrial model plant. Thus, the economic impact of the relatively fixed costs of necessary equipment are reduced in plants with larger throughputs.

8.2 BASIS FOR ANNUALIZED COSTS

Annualized costs are the sum of operating costs plus capital charges. Capital charges include capital recovery costs, as well as costs due to taxes, insurance, and administration (Vatavuk, 1980). Operating costs include utilities, operating labor, and maintenance (labor and materials). Credit for the value of recovered solvent is based on a solvent cost of $0.44 per liter ($1.65 per gal) (Carson, 1981). Table 8-7 describes how the annualized costs were calculated and Table 8-8 presents the operational data upon which the costs were based.

Table 8-2. CAPITAL COSTS FOR A NEW SMALL COMMERCIAL MODEL PLANT (14,000 kg articles cleaned per year)

Equipment system	Description	Quantity	Unit cost (first quarter, 1981 dollars)
Dry cleaning equipment	16 Kg washer/extractor	1	7,500
	100 L/hr petroleum still	1	2,100
	7 element cartridge filter	1	1,300
	Subtotal		10,900
	(See Table 8-1 for costs of standard and recovery dryers)		
Process equipment	Deluxe spotting board	1	1,200
	Pre-spotting unit and table	1	580
	Automatic pants topper and legger	1	7,990
	Men's shoulder puff iron	1	280
	Form finisher	1	1,830
	Silk utility press with iron attachment	1	4,150
	Three head puff iron set	1	770
	Subtotal		16,800
Handling and receiving equipment	SA-600 conveyor with automatic dial and file	1	3,260
	Assembly Arc	1	490
	Counters (5 ft. length)	2	750
	Marking counter	1	560
	Slick rail system	1	1,000
	Subtotal		6,060
Boiler system	15 Hp natural gas boiler	1	5,540
	Condensate return system	1	760
	5 press air vacuum	1	810
	5 Hp air compressor	1	2,630
	Subtotal		9,740
Miscellaneous equipment	200 gal free standing solvent storage tank with pump and piping	1	600
	Cash register	1	1,300
	Baskets	3	120
	Subtotal		2,020
	Total Equipment Cost[a]		45,520
Additional costs[b]	Taxes, freight and instrumentation		8,200
	Installation costs		4,550
	Total Capital Cost[c]		$58,300

Not included are costs for supplies and the cost to lease or construct a building (2,400 square feet required to house equipment plus 4,300 square feet for parking and miscellaneous usages).

[a] Kirk, 1981

[b] Vatavuk, 1980

[c] Does not include dryers and ancillary cooling equipment.

Table 8-3. CAPITAL COSTS FOR A NEW MEDIUM COMMERCIAL MODEL PLANT (32,000 kg articles cleaned per year)

Equipment system	Description	Quantity	Unit cost (first quarter, 1981 dollars)
Dry cleaning equipment	23 kg washer/extractor	1	13,400
	190 L/hr petroleum still	1	4,200
	10 element cartridge filter	1	1,800
	Subtotal		19,400
	(See Table 8-1 for costs of standard and recovery dryers)		
Process equipment	Deluxe spotting board	1	1,200
	Pre-spotting unit and table	1	580
	Automatic pants topper and legger	1	7,990
	Men's shoulder puff iron	1	280
	Form finisher	1	1,830
	Silk utility press with iron attachment	1	4,150
	Three head puff iron set	1	770
	Subtotal		16,800
Handling and receiving equipment	SA-600 conveyor with automatic dial and file	1	3,260
	Assembly Arc	1	490
	Counters (5 ft. length)	2	750
	Marking counter	1	560
	Slick rail system	1	1,000
	Subtotal		6,060
Boiler system	15 Hp natural gas boiler	1	5,540
	Condensate return system	1	760
	5 press air vacuum	1	810
	5 Hp air compressor	1	2,630
	Subtotal		9,740
Miscellaneous equipment	200 gal free standing solvent storage tank with pump and piping	1	600
	Cash register	1	1,300
	Baskets	3	120
	Subtotal		2,020
	Total Equipment Cost[a]		54,020
Additional costs[b]	Taxes, freight and instrumentation		9,720
	Installation costs		5,400
	Total Capital Cost[c]		$69,100

Not included are costs for supplies and the cost to lease or construct a building (2,400 square feet required to house equipment plus 4,300 square feet for parking and miscellaneous usages).

[a] Kirk, 1981

[b] Vatavuk, 1980

[c] Does not include dryers and ancillary cooling equipment.

Table 8-4. CAPITAL COSTS FOR A NEW LARGE COMMERCIAL MODEL PLANT (82,000 kg articles cleaned per year)

Equipment system	Description	Quantity	Unit cost (first quarter, 1981 dollars)
Dry cleaning equipment	45 Kg washer/extractor	1	26,900
	380 L/hr petroleum still	1	8,360
	21 element cartridge filter	1	3,900
	Subtotal		39,160
	(See Table 8-1 for costs of standard and recovery dryers)		
Process equipment	Deluxe spotting board	1	1,200
	Pre-spotting unit and table	1	580
	Automatic pants topper and legger	1	7,990
	Men's shoulder puff iron	1	280
	Steam tunnel with automatic loader and moisturizer	1	8,990
	Form finisher	1	1,830
	Silk utility press with iron attachment	1	4,150
	Three head puff iron set	1	770
	Leather press	1	3,520
	Utility press with iron attachment	1	4,150
	Drapery pleater with power winch, steam and dry chamber	1	3,250
	Subtotal		36,710
Handling and receiving equipment	SA-700 conveyor with automatic dial and file	1	3,560
	Assembly Arc	1	680
	Counters (5 ft. length)	3	1,125
	Marking counter	1	560
	Slick rail system	1	1,500
	Subtotal		7,425
Boiler system	40 Hp natural gas boiler	1	11,880
	Condensate return system	1	1,450
	8 press air vacuum	1	900
	5 Hp air compressor	1	2,630
	Subtotal		16,860
Miscellaneous equipment	500 gal free standing solvent storage tank with pump and piping	1	900
	Cash register	1	1,300
	Baskets	5	300
	Subtotal		2,500
	Total Equipment Cost[a]		102,660
Additional costs[b]	Taxes, freight and instrumentation		18,480
	Installation costs		10,270
	Total Capital Cost[c]		$131,400

Not included are costs for supplies and cost to lease or construct a building (4,000 square feet required plus 7,150 square feet for parking and miscellaneous usages).

[a] Kirk, 1981

[b] Vatavuk, 1980

[c] Does not include dryers and ancillary cooling equipment.

Table 8-5. CAPITAL COSTS FOR A NEW SMALL INDUSTRIAL MODEL PLANT (182,000 kg articles cleaned per year)

Equipment system	Description	Quantity	Unit cost (first quarter, 1981 dollars)
Dry cleaning equipment	115 kg washer/extractor	1	55,000
	1900 L/hr petroleum still	1	51,390
	21 element cartridge filter	3	11,700
	Subtotal		118,090
	(See Table 8-1 for costs of standard and recovery dryers)		
Process equipment	JD-12-580 gas heated, hot water system	1	11,430
	System 2000 steam tunnel	1	26,000
	Automatic garment sorting system and storage lines	1	18,650
	Subtotal		56,080
Boiler system	180 Hp gas/oil dual fuel boiler	1	26,300
	Condensate return system	1	3,000
	8 press air vacuum	2	1,800
	5 Hp air compressor	2	5,260
	Subtotal		36,360
Miscellaneous equipment	4,000 gal underground solvent storage tank with pumps and piping	1	1,500
	Baskets	9	450
	1,000 gal still waste holding tank with pump filter	1	1,000
	Subtotal		6,950
	Total Equipment Cost[a]		217,780
Additional costs[b]	Taxes, freight and instrumentation		39,150
	Installation costs		21,750
	Total Capital Cost[c]		$278,400

Not included are costs for supplies and cost to lease or construct a building (8,000 square feet required plus 14,300 square feet required for parking and miscellaneous usages).

[a] Kirk, 1981

[b] Vatavuk, 1981

[c] Does not include dryers and ancillary cooling equipment.

Table 8-6. CAPITAL COSTS FOR A NEW LARGE INDUSTRIAL MODEL PLANT (635,000 kg articles cleaned per year)

Equipment system	Description	Quantity	Unit cost (first quarter, 1981 dollars)
Dry cleaning equipment	225 kg washer/extractor	2	166,600
	1900 L/hr petroleum still	3	154,170
	Subtotal		320,770
	(See Table 8-1 for costs of standard and recovery dryers)		
Process equipment	JD-12-580 gas heated, hot water system	1	11,430
	System 2000 steam tunnel	1	26,000
	Automatic garment sorting system and storage lines	1	18,650
	Subtotal		56,080
Boiler system	180 Hp gas/oil dual fuel boiler	1	26,300
	Condensate return system	1	3,000
	8 press air vacuum	2	1,800
	5 Hp air compressor	2	5,260
	Subtotal		36,360
Miscellaneous equipment	4,000 gal underground solvent storage tank with pumps and piping	1	1,500
	Baskets	9	450
	1,000 gal still waste holding tank with pump filter	1	1,000
	Subtotal		6,950
	Total Equipment Cost[a]		420,160
Additional costs[b]	Taxes, freight and instrumentation		75,630
	Installation costs		42,020
	Total Capital Cost[c]		$537,800

Not included are costs for supplies and cost to lease or construct a building (8,000 square feet required plus 14,300 square feet required for parking and miscellaneous usages).

[a] Kirk, 1981

[b] Vatavuk, 1981

[c] Does not include dryers and ancillary cooling equipment.

Table 8-7. CALCULATION OF ANNUALIZED COSTS OF AFFECTED DRY CLEANING EQUIPMENT

Cost component	Method of calculation
Operating costs	
Utilities Steam	Cost per year = $\frac{\text{boiler hp}}{\text{dryer}} \times \frac{\text{34.5 lbs steam/hr}}{\text{boiler hp}} \times \frac{\text{dryers}}{\text{plant}} \times \frac{\text{operating days}}{\text{year}} \times \frac{\text{operating hrs}}{\text{day}} \times \frac{\text{cost}}{\text{lb steam}}$ o Daily steam demand is assumed equal to the hours of dryer operation (dry cycle time x loads dried per day). o Steam cost = \$0.02/kg (\$0.009/lb). o Commercial plants operate 250 days per year, and industrial plants operate 260 days per year. o 34.5 lbs steam per hour per boiler horsepower is a constant of conversion (Babcock, 1978).
Electricity	Cost per year = $\frac{\text{motor hp}}{\text{dryer}} \times \frac{\text{0.746 kW}}{\text{motor hp}} \times \frac{\text{dryers}}{\text{plant}} \times \frac{1}{\text{motor efficiency}} \times \frac{\text{operating days}}{\text{year}} \times \frac{\text{operating hrs}}{\text{day}} \times \frac{\text{cost}}{\text{kWh}}$ o Motor efficiency is assumed to be 60%. o Operating hours per day are based on each model plant's dryer cycle time per load and the number of loads per day. o Operating days per year same as steam (see above). o Electricity cost per kWh = \$0.06. o 0.746 kW per horsepower is a constant of conversion (Babcock, 1978).
Operating labor	Cost per year = $\frac{\text{load/unload time}}{\text{dryer-load}} \times \frac{\text{dryers}}{\text{plant}} \times \frac{\text{loads}}{\text{day}} \times \frac{\text{operating days}}{\text{year}} \times \frac{\text{cost}}{\text{worker-hour}}$ o Load/unload time = 0.17 hrs for 23 Kg and 45 Kg dryers, and 0.33 hrs for 180 Kg dryers. o Operating days per year same as steam (see above). o Labor cost per worker-hour = \$8.42.
Maintenance and Supplies	Cost per year = $\frac{\text{1 worker-hr}}{\text{dryer-week}} \times \frac{\text{dryers}}{\text{plant}} \times \frac{\text{operating days}}{\text{year}} \times \frac{\text{week}}{\text{5 operating days}} \times \frac{\text{cost}}{\text{worker-hr}} \times$ 2.0 materials supplement o Maintenance labor cost per worker-hour = \$8.30. o Maintenance labor and materials costs are equal (based on computed costs of hourly labor or required materials, whichever is greater).
Capital charges	
Overhead	Taxes, insurance and administration = 4% of total capital costs.
Capital recovery	Capital recovery factor = $\frac{i(1+i)^n}{(1+i)^n - 1} \times$ (total capital cost) o i = interest rate of 10%. o n = equipment life of 30 years.
Recovered solvent credit	Solvent saved per year = total annual emission reduction $= \frac{\text{Kg solvent saved}}{\text{Kg throughput}} \times \frac{\text{kg throughput}}{\text{year}} \times \frac{\text{cost}}{\text{kg solvent}}$ o Assuming 65 to 95 percent reduction of total uncontrolled VOC emissions for the recovery dryer (13.3 to 18.5 Kg VOC saved per 100 Kg articles cleaned). o Average solvent cost = \$0.56/Kg.

Table 8-8. OPERATING PARAMETERS PER DRYER FOR STANDARD AND RECOVERY DRYERS AND ANCILLARY EQUIPMENT

Model plants	Equipment[1]	Steam		Electricity			
				Fan		Tumbler	
		Boiler horsepower	Operating hours[2]	Horsepower	Operating hours[2]	Horsepower	Operating hours[2]
Small commercial	SD	3.2	1.4	0.33	1.5	0.33	1.4
	RD	1.5	1.4	0.5	1.7	0.33	1.6
	CT[3]					0.5	8.0
	RC[4]					3.0	1.7
Medium commercial	SD	3.2	3.7	0.33	4.0	0.33	3.7
	RD	1.5	3.7	0.5	4.6	0.33	4.3
	CT[3]					0.5	8.0
	RC[4]					3.0	4.6
Large commercial	SD	8.3	4.8	1.5	5.1	0.5	4.8
	RD	2.5	4.6	0.75	5.6	0.75	5.3
	CT[3]					0.5	8.0
	RC[4]					4.0	5.6
Small industrial	SD	8.3	4.5	1.5	4.7	0.5	4.5
	RD	2.5	4.3	0.75	5.1	0.75	4.9
	CT[3]					0.75	8.0
	RC[4]					10.0	5.1
Large industrial	SD	3.2	6.0	25.0	6.3	5.0	6.0
	RD	2.5	5.7	0.75	6.6	0.75	6.4
	CT[3]					0.75	8.0
	RC[4]					31.0	6.6

[1] SD = Standard dryer.
RD = Recovery dryer.
CT = Cooling tower.
RC = Refrigerated chiller.

[2] Operating hours per dryer per day.

[3] Total horsepower and operating hours for each cooling tower.

[4] Total horsepower and operating hours for each refrigerated chiller.

Primary utilities included under annual operating costs were steam and electricity. The annual steam cost of $0.02 per kilogram ($0.009 per lb) was based on equipment manufacturers' estimates of steam demand (Cissel, 1981; Challenge-Cook, 1981; Hoyt, 1981), estimates of operating hours based on model plant throughput, and a cost of steam (in dollars per kilogram generated) derived from current fuel cost estimates (Vatavuk, 1980). Electrical requirements were derived from manufacturers' electrical demand specifications (usually in motor horsepower), operating time estimates based on model plant throughput, and a national average cost of electricity ($0.06 per kWh) for commercial customers (Vatavuk, 1980). An operating efficiency of 60 percent was assumed for electric motors (Neveril, 1978) and electrical demand from cooling towers and refrigerated chillers was assumed to remain constant over the entire working day. (See Table 8-8 for operating hours per day.)

Operating labor cost estimates of $8.42 per worker-hour were taken from national statistics for average hourly wages in the "Wholesale and Retail Trade Category" with the addition of 56 percent for payroll and plant overhead (Vatavuk, 1980). A work time of 1 worker-hour of operating labor per dryer per day was assumed (Jernigan and Lutz, 1980).

Estimated annual maintenance costs include both labor and materials. A maintenance labor cost of $8.30 per worker-hour was calculated from hourly rates that included a 26 percent plant overhead factor, with hours based on field test and plant survey data (Vatavuk, 1980). Maintenance materials costs were determined as 100 percent of annual maintenance labor costs in the absence of exact materials cost data (Vatavuk, 1980). When material costs were available, maintenance costs were represented as twice the cost of labor or materials, whichever was higher.

The cost associated with capital recovery was based on a 10 percent interest rate over the 30 year expected equipment life (Landon, 1975). Taxes, insurance, and administrative costs resulting from the operation of emission control equipment were included as 4 percent of the total capital cost (Neveril, 1978).

Annual credits for recovered solvent were based on experimentally determined solvent emission rates for emission control equipment. For example, the maximum emission reduction resulting from the installation of emission control equipment in commercial plants was the difference between the nominal Alternative I (baseline) emission rate of 23 kilograms VOC per 100 kilograms of articles cleaned and the nominal Alternative III emission rate of 8.5 kilograms VOC per 100 kilograms of articles cleaned. It was also assumed that all of the emission reduction from the baseline was recovered in a reusable form (Jernigan and Lutz, 1980). Solvent costs were taken from industry quotations, the average being $0.44 per liter ($1.65 per gal) (Carson, 1981). The difference from baseline control costs was computed as the difference between total annual operating costs of existing and mandated emission control equipment.

8.3 COST ANALYSIS OF REGULATORY ALTERNATIVES

The cost estimates for three regulatory alternatives ranging from existing baseline controls (Alternative I) to the most stringent controls (Alternative III) are briefly discussed in this chapter. For additional information on regulatory alternatives, refer to Chapter 6.

Alternative I represents current emission control procedures in the industry and is included to provide a baseline for comparison with additional control alternatives. Nominal emissions of approximately 23 kilograms for plants using solvent filtration and 22 kilograms VOC per 100 kilograms of articles cleaned for plants omitting filtration are typical under this alternative.

Alternative II would require plants to reduce overall VOC emissions through the implementation of effective operating and maintenance procedures. This alternative would result in no specific emission reductions beyond baseline emissions because reductions from leak repair and cartridge drainage have not been quantified. Therefore, Alternative II nominal emission rates remain unchanged from those given under Alternative I.

Alternative III incorporates all requirements of Alternative II with the addition that recovery dryers are required in place of conventional dryers with a resultant 80 percent reduction in nominal dryer emissions. Solvent emissions under Alternative III are reduced in plants using filtration from the baseline nominal rate of 23 kilograms to a controlled nominal rate of 8.5 kilograms VOC per 100 kilograms of articles cleaned.

Plants that omit solvent filtration would have nominal baseline emissions of 22 kilograms reduced to 7.5 kilograms VOC per 100 kilograms of articles cleaned under control Alternative III.

8.3.1 New Facilities

As discussed in Chapter 9, Section 9.1.8, a one percent annual growth rate in new plants has been projected for the industrial petroleum dry cleaning industry while zero growth is projected for the commercial petroleum dry cleaning industry. These projected growth rates and a 3.3 percent annual equipment replacement rate were used to determine the economic impacts of each regulatory alternative assuming that any replacement equipment installed after the proposal date of the standards may be subject to their requirements (Landon, 1975).

The three regulatory alternatives were applied to each model plant to determine the cost due to compliance. The capital and annualized costs of the three alternatives are presented in Tables 8-9 through 8-13 for the five model plants. Additionally, the cost effectiveness associated with the implementation of Alternative III is also presented. The cost effectiveness of a given regulatory alternative is defined as the difference in annualized costs between the given alternative and Alternative I (baseline), per megagram of emission reduction resulting from the adoption of the given regulatory alternative. The cost effectiveness of Alternative II, however, cannot be specified because the emission reductions and costs associated with Alternative II are not quantifiable. It is assumed that new and existing cleaning plants 5 or more years after proposal of the NSPS will be more efficient. Thus, cartridge filters will be employed by all plants that use filtration, with any remaining plants being required by the NSPS to use cartridge filters, as applicable. The good housekeeping provisions of Alternatives II and III should provide the incentive for the industry to maintain adequate maintenance procedures.

Alternative I and II capital and annualized costs are equivalent because specific labor costs and solvent recovery credits cannot be specified under the good housekeeping provisions of Alternative II. Total annualized costs are given for the recovery dryer using existing process water for cooling, the recovery dryer with cooling tower, and

Table 8-9. CAPITAL AND ANNUALIZED COSTS OF CONTROLS IN A SMALL COMMERCIAL MODEL PLANT
(costs are in thousands of first quarter 1981 dollars)

Cost parameters	Regulatory Alternatives		
	I	II	III
Capital costs[e]			
Equipment	3.07	3.07	17.94
Taxes, freight, and instrumentation	0.55	0.55	3.23
Direct and indirect installation	0.23	0.23	1.34
Total capital costs	3.85	3.85	22.51
Annualized costs			
Operating costs			
Steam	0.35	0.35	0.16
Electricity	0.02	0.02	0.17
Operating labor	2.15	2.15	2.15
Annual maintenance (labor and materials)	0.83	0.83	0.83
Subtotal, direct costs	3.35	3.35	3.31
Capital charges			
Capital recovery	0.41	0.41	2.39
Administration, taxes, and insurance	0.15	0.15	0.90
Subtotal, indirect costs	0.56	0.56	3.29
Total operating costs and capital charges	3.91	3.91	6.70
Recovered solvent value	0	d	(1.04-1.45)
Total annualized costs	3.91	3.91	5.25-5.66
Difference from baseline total control costs	0	d	1.34-1.75
Total annualized cost with cooling tower	b	b	5.49-5.90
Difference from baseline total control costs with cooling tower	b	b	1.58-1.99
Total annualized cost with no additional cooling water equipment	b	b	4.68-5.09
Difference from baseline total control costs with no additional cooling water equipment	b	b	0.77-1.18
Total emission reduction for each control alternative in Mg VOC per year	0	d	1.86-2.59
Total cost effectiveness for each control alternative in thousands of dollars per Mg of VOC emission reduction[c,e]	b	d	0.68-0.72
Total cost effectiveness with a cooling tower	b	b	0.77-0.85
Total cost effectiveness with no additional cooling water equipment	b	b	0.41-0.46

[a] Numbers in parenthesis represent thousands of dollars saved.

[b] Not applicable.

[c] Cost effectiveness is defined as the difference between baseline and the given regulatory alternative total annualized cost per megagram of emission reduction between baseline VOC emissions and that of the given control alternative.

[d] Not quantifiable.

[e] Regulatory Alternative III costs include capital and annualized costs of both recovery dryer and refrigerated chiller.

Table 8-10. CAPITAL AND ANNUALIZED COSTS OF CONTROLS IN A MEDIUM COMMERCIAL MODEL PLANT
(costs are in thousands of first quarter 1981 dollars)

Cost parameters	Regulatory Alternatives I	II	III
Capital costs[e]			
Equipment	3.07	3.07	17.94
Taxes, freight, and instrumentation	0.55	0.55	3.23
Direct and indirect installation	0.23	0.23	1.34
Total capital costs	3.85	3.85	22.51
Annualized costs			
Operating costs			
Steam	0.92	0.92	0.43
Electricity	0.05	0.05	0.39
Operating labor	2.86	2.86	2.86
Annual maintenance (labor and materials)	0.83	0.83	0.83
Subtotal, direct costs	4.66	4.66	4.51
Capital charges			
Capital recovery	0.41	0.41	2.39
Administration, taxes, and insurance	0.15	0.15	0.90
Subtotal, indirect costs	0.56	0.56	3.29
Total operating costs and capital charges	5.22	5.22	7.80
Recovered solvent value	0	d	(2.38-3.32)
Total annualized costs	5.22	d	4.48-5.42
Difference from baseline total control costs	0	d	(0.74)-0.20
Total annualized cost with cooling tower			4.24-5.18
Difference from baseline total control costs with cooling tower			(0.04-0.98)
Total annualized cost with no additional cooling water equipment			3.91-4.85
Difference from baseline total control costs with no additional cooling water equipment			(0.37-1.31)
Total emission reduction for each control alternative in Mg VOC per year	0	d	4.25-5.93
Total cost effectiveness for each control alternative in thousands of dollars per Mg of VOC emission reduction[c,e]	b	d	(0.17)-0.03
Total cost effectiveness with a cooling tower	b	b	(0.01-0.17)
Total cost effectiveness with no additional cooling water equipment	b	b	(0.09-0.22)

[a] Numbers in parenthesis represent thousands of dollars saved.

[b] Not applicable.

[c] Cost effectiveness is defined as the difference between baseline and the given regulatory alternative total annualized cost per megagram of emission reduction between baseline VOC emissions and that of the given control alternative.

[d] Not quantifiable.

[e] Regulatory Alternative III costs include capital and annualized costs of both recovery dryer and refrigerated chiller.

Table 8-11. CAPITAL AND ANNUALIZED COSTS OF CONTROLS IN A LARGE COMMERCIAL MODEL PLANT (costs are in thousands of first quarter 1981 dollars)

Cost parameters	Regulatory Alternatives		
	I	II	III
Capital costs[e]			
Equipment	5.13	5.13	18.73
Taxes, freight, and instrumentation	0.92	0.92	3.37
Direct and indirect installation	0.39	0.39	1.40
Total capital costs	6.44	6.44	23.50
Annualized costs			
Operating costs			
Steam	3.09	3.09	0.89
Electricity	0.19	0.19	0.96
Operating labor	3.22	3.22	3.22
Annual maintenance (labor and materials)	0.83	0.83	0.83
Subtotal, direct costs	7.33	7.33	5.90
Capital charges			
Capital recovery	0.68	0.68	2.49
Administration, taxes, and insurance	0.26	0.26	0.94
Subtotal, indirect costs	0.94	0.94	3.43
Total operating costs and capital charges	8.27	8.27	9.33
Recovered solvent value	0	d	(6.11-8.50)
Total annualized costs	8.27	8.27	0.83-3.22
Difference from baseline total control costs	0	d	(5.05-7.44)
Total annualized cost with cooling tower	b	b	(0.12)-2.27
Difference from baseline total control costs with cooling tower	b	b	(6.00-8.39)
Total annualized cost with no additional cooling water equipment	b	b	(0.45)-1.94
Difference from baseline total control costs with no additional cooling water equipment	b	b	(6.33-8.72)
Total emission reduction for each control alternative in Mg VOC per year	0	d	10.9-15.2
Total cost effectiveness for each control alternative in thousands of dollars per Mg of VOC emission reduction[c,e]	b	d	(0.46-0.49)
Total cost effectiveness with a cooling tower	b	b	(0.55-0.56)
Total cost effectiveness with no additional cooling water equipment	b	b	(0.57-0.58)

[a] Numbers in parenthesis represent thousands of dollars saved.

[b] Not applicable.

[c] Cost effectiveness is defined as the difference between baseline and the given regulatory alternative total annualized cost per megagram of emission reduction between baseline VOC emissions and that of the given control alternative.

[d] Not quantifiable.

[e] Regulatory Alternative III costs include capital and annualized costs of both recovery dryer and refrigerated chiller.

Table 8-12. CAPITAL AND ANNUALIZED COSTS OF CONTROLS IN A SMALL INDUSTRIAL MODEL PLANT
(costs are in thousands of first quarter 1981 dollars)

Cost parameters	Regulatory Alternatives I	II	III
Capital costs[e]			
Equipment	15.39	15.39	53.05
Taxes, freight, and instrumentation	2.77	2.77	9.55
Direct and indirect installation	1.15	1.15	3.98
Total capital costs	19.31	19.31	66.58
Annualized costs			
Operating costs			
Steam	9.05	9.05	2.60
Electricity	0.54	0.54	2.24
Operating labor	5.58	5.58	5.58
Annual maintenance (labor and materials)	2.59	2.59	2.59
Subtotal, direct costs	17.76	17.76	13.01
Capital charges			
Capital recovery	2.05	2.05	7.06
Administration, taxes, and insurance	0.77	0.77	2.67
Subtotal, indirect costs	2.82	2.82	9.73
Total operating costs and capital charges	20.58	20.58	22.74
Recovered solvent value	0	d	(13.56-18.86)
Total annualized costs	20.58	20.58	3.88-9.18
Difference from baseline total control costs	0	d	(11.40-16.70)
Total annualized cost with cooling tower	b	b	2.10-7.40
Difference from baseline total control costs with cooling tower	b	b	(13.18-18.48)
Total annualized cost with no additional cooling water equipment	b	b	1.24-6.54
Difference from baseline total control costs with no additional cooling water equipment	b	b	(14.04-19.34)
Total emission reduction for each control alternative in Mg VOC per year	0	d	24.2-33.7
Total cost effectiveness for each control alternative in thousands of dollars per Mg of VOC emission reduction[c,e]	b	d	(0.47-0.50)
Total cost effectiveness with a cooling tower	b	b	(0.54-0.55)
Total cost effectiveness with no additional cooling water equipment	b	b	(0.57-0.58)

[a] Numbers in parenthesis represent thousands of dollars saved.

[b] Not applicable.

[c] Cost effectiveness is defined as the difference between baseline and the given regulatory alternative total annualized cost per megagram of emission reduction between baseline VOC emissions and that of the given control alternative.

[d] Not quantifiable.

[e] Regulatory Alternative III costs includes capital and annualized costs of both recovery dryer and refrigerated chiller.

Table 8-13. CAPITAL AND ANNUALIZED COSTS OF CONTROLS IN A LARGE INDUSTRIAL MODEL PLANT
(costs are in thousands of first quarter 1981 dollars)

Cost parameters	Regulatory Alternatives I	II	III
Capital costs[e]			
Equipment	68.00	68.00	140.94
Taxes, freight, and instrumentation	12.24	12.24	25.37
Direct and indirect installation	5.10	5.10	10.57
Total capital costs	85.34	85.34	176.88
Annualized costs			
Operating costs			
Steam	31.00	31.00	9.20
Electricity	7.27	7.27	7.82
Operating labor	10.11	10.11	20.84
Annual maintenance (labor and materials)	1.73	1.73	6.91
Subtotal, direct costs	50.11	50.11	44.77
Capital charges			
Capital recovery	9.05	9.05	18.76
Administration, taxes, and insurance	3.41	3.41	7.08
Subtotal, indirect costs	12.46	12.46	25.84
Total operating costs and capital charges	62.57	62.57	70.61
Recovered solvent value	0	d	(47.30-65.79)
Total annualized costs	62.57	62.57	4.82-23.31
Difference from baseline total control costs	0	d	(39.26-57.75)
Total annualized cost with cooling tower	b	b	(1.50)-16.99
Difference from baseline total control costs with cooling tower	b	b	(45.58-64.07)
Total annualized cost with no additional cooling water equipment	b	b	(3.60)-14.89
Difference from baseline total control costs with no additional cooling water equipment	b	b	(47.68-66.17)
Total emission reduction for each control alternative in Mg VOC per year	0	d	84.5-118
Total cost effectiveness for each control alternative in thousands of dollars per Mg of VOC emission reduction[c,e]	b	d	(0.47-0.49)
Total cost effectiveness with a cooling tower	b	b	(0.54-0.55)
Total cost effectiveness with no additional cooling water equipment	b	b	(0.56-0.57)

[a] Numbers in parenthesis represent thousands of dollars saved.

[b] Not applicable.

[c] Cost effectiveness is defined as the difference between baseline and the given regulatory alternative total annualized cost per megagram of emission reduction between baseline VOC emissions and that of the given control alternative.

[d] Not quantifiable.

[e] Regulatory Alternative III costs includes capital and annualized costs of both recovery dryer and refrigerated chiller.

recovery dryer with refrigerated chiller to illustrate the cost impacts associated with different methods of supplying cooling water for the recovery dryer. Included in the annualized cost, is a credit due to the value of recovered petroleum solvent. The solvent credit increases with increasing plant throughput and eventually reduces the annualized cost of Alternative III below the annualized cost of baseline (Alternative I). The total annualized cost of a recovery dryer with a cooling tower is less than the annualized cost of a recovery dryer with a refrigerated chiller. However, comparative analyses of the alternatives and model plants are performed using the cost data of a recovery dryer and refrigerated chiller as a worst case analysis. The capital cost difference between Alternative I and Alternative III is based on the use of a refrigerated chiller for cooling water supply in the recovery dryer, in addition to the cost difference resulting from the use of a recovery dryer instead of a standard dryer.

Capital costs in small commercial plants under Regulatory Alternative III, as illustrated in Table 8-9, increase by approximately 83 percent beyond baseline (Alternative I) capital costs. Under Alternative III, annualized costs increase by as much as 45 percent beyond Alternative I annualized costs due to the installation of recovery dryers with refrigerated chillers. The cost effectiveness of Regulatory Alternative III ranges from $680 to $720 expended per megagram of emission reduction when recovery dryer cooling water is supplied by a refrigerated chiller. The adoption of Regulatory Alternative III in a small commercial model plant will result in a capital cost of about $22,500, annualized costs ranging from $5,250 to $5,660 per year, and an overall cost effectiveness ranging from $410 to $850 expended per megagram of VOC emission reduction, depending on the source of recovery dryer cooling water.

Capital costs in medium commercial model plants (Table 8-10) are equal to those in small commercial plants, and annualized costs increase with the increased throughput. Alternative I annualized costs of $5,220 are decreased to a minimum of $4,480 or increased to a maximum of $5,420 with the installation of recovery dryers under Alternative III. Alternative III cost effectiveness varies from a net cost of $30 to a net savings of $170 per megagram of emission reduction with refrigerated chillers supplying recovery dryer cooling water. Again, the cost effectiveness of Regulatory Alternative III depends on the equipment used to supply recovery dryer cooling water, with cost effectiveness ranging from a savings of $220 to a cost of $30 per megagram of emission reduction.

Table 8-11 illustrates the regulatory cost impacts on a large commercial model plant. As in the previous commercial plants, the high capital costs of recovery dryers result in a 70 percent increase in capital costs of Regulatory Alternative III. For the first time, the value of recovered solvent under Alternative III results in a savings in annualized costs of up to $7,440 relative to baseline. This savings produces a range of cost effectiveness for Alternative III of $460 to $490 saved per megagram of emission reduction with refrigerated chillers supplying recovery dryer cooling water.

The cost impacts of the regulatory alternatives on a small industrial model plant are illustrated in Table 8-12. Again, capital costs associated with the installation of recovery dryers are approximately 2.5 times greater than those of baseline standard equipment. Annualized costs under Regulatory Alternative III range from a savings of $11,400 to $16,700 relative to baseline with refrigerated chillers supplying recovery dryer cooling water. Similarly, the cost effectiveness of Alternative III varies slightly from $470 to $500 saved per megagram of emission reduction.

Capital costs in large industrial model plants (Table 8-13) increase by 110 percent with the installation of eight 45 kilogram recovery dryers to replace two 180 kilogram standard dryers as specified under Regulatory Alternative III. Annualized costs associated with Alternative III vary widely from $4,820 to $23,300 with refrigerated chillers supplying recovery dryer cooling water. The cost effectiveness of Alternative III varies between savings of $470 and $490 per megagram of emission reduction, with refrigerated chillers supplying recovery dryer cooling water.

Table 8-14 summarizes the derivation of the cost effectiveness of Regulatory Alternatives II and III in the five model plants. The cost effectiveness of Regulatory Alternative III reverts from a net cost to a

Table 8-14. SUMMARY OF THE INCREMENTAL ANNUALIZED COST, EMISSIONS REDUCTION, AND COST EFFECTIVENESS FROM BASELINE TO REGULATORY ALTERNATIVE III IN MODEL PLANTS[a]
(costs in first quarter 1981 dollars)

Model plants	Incremental annualized cost[b] from baseline controls (in thousands of dollars)	Emission reduction $\left(\frac{\text{Mg VOC}}{\text{yr}}\right)$	Cost effectiveness of control alternatives $\left(\frac{\text{incremental annualized cost in } \$10^3}{\text{Mg emission reduction}}\right)$
Small commercial	1.50-1.91	1.86-2.59	0.74-0.81
Medium commercial	(0.39)-0.55	4.25-5.93	(0.09)-0.09
Large commercial	(4.56-6.92)	10.9-15.2	(0.42-0.46)
Small industrial	(14.93-20.23)	24.2-33.7	(0.60-0.62)
Large industrial	(31.84-50.33)	84.5-118	(0.38-0.43)

[a] Regulatory Alternative II emission reductions and annualized costs impacts are not quantifiable and are, consequently, not presented.

[b] Annualized cost difference for modified Alternative III is based on recovery dryer cooling water being supplied by a refrigerated chiller.

[c] Numbers in parentheses represent thousands of dollars saved.

savings (credit) in the medium commercial model plant. Thus, a plant of this type would be expected to operate under "break-even" conditions, with Alternative III control equipment and procedures producing no additional costs nor resulting in any savings. In larger plants, the savings generated under Regulatory Alternative III steadily increase and reach a peak of $470 to $500 saved per megagram of VOC emission reduction in the small industrial model plant. Finally, the range of cost effectiveness in the large industrial model plant ($470 to $490) represents a slight decline from that of the small industrial plant.

8.3.2 Modification or Reconstruction

Modification or reconstruction as defined in the Clean Air Act will be applied to the petroleum dry cleaning industry on a case-by-case basis. Conventional dryers in an existing plant continuously vent VOC emissions to the atmosphere during dryer operation. Modifications that may adversely affect the dryer operation are rare and should not increase VOC emissions because the capacity or throughput of these devices cannot be increased by add-on devices. Because each individual piece of major dry cleaning equipment is defined as an affected facility, modification and reconstruction will be limited to maintenance repairs on individual items of equipment. Reconstruction of a dryer or vacuum still would normally be limited to the replacement of such items as defective steam coils, motors or pumps. Typically, the cost of these separate items is less than 50 percent of the unit cost of the dry cleaning equipment. A modification provision to regulate this equipment by way of accumulated modification costs which are to be tallied beginning the day after proposal of the standard until the costs for modification equal or exceed 50 percent of the equipment costs, will have very little, if any, impact on emission reduction because of the small number of plants that may be affected by this provision.

Because washer/extractors are high-cost items, ranging from $13,400 for a 40 lb washer/extractor to $83,800 for a 500 lb washer/extractor, a certain level of modification or reconstruction can be expected. As is the case for dryers, modification or reconstruction for washer/extractors is usually limited to the replacement of worn pumps and motors which are each less than 50 percent of the unit cost of the washer/extractor.

Because there are no emission control measures for washer/extractors other than good housekeeping, modification or reconstruction provisions will have negligible affects. (For additional information on modification and reconstruction see Chapter 5.)

8.3.3 Nationwide Control Cost Summary

The nationwide cost impacts of the Regulatory Alternatives in the five model plants have been analyzed for the periods of 5 and 10 years following proposal of the Standards. Projections of the number of plants in each of the five model plant categories (see Section 9.1) are based on a zero growth rate for commercial plants and a 1 percent growth rate for industrial plants. Projected increases in the number of affected facilities having an impact on capital and operating costs (dryers) are based on a 30 year expected life for dry cleaning equipment (Landon, 1975), resulting in an annual replacement rate of 3.3 percent for existing affected facilities. The impacts of the construction of new petroleum solvent dry cleaning plants and the replacement of existing dryers are discussed in detail in Chapter 9.

In determining the nationwide cost impacts of the Regulatory Alternatives (Tables 8-15 and 8-16), capital costs were derived by multiplying the total number of affected model plants in the given time span by the capital costs listed in Tables 8-9 to 8-13. Annualized costs were determined by multiplying the annualized cost values contained in these same tables by the cumulative number of affected model plants existing through each year. Nationwide emission reductions were based on Alternative III emission rate reductions given in Table 7-2. As previously mentioned in Chapter 7, Alternative II emission reductions are not quantifiable. Consequently, there is no cost effectiveness associated with Alternative II. Finally, the cost effectiveness of Regulatory Alternative III in the model plants was calculated as the difference in annualized costs between Alternative III and Alternative I, divided by the resultant emission reduction.

Table 8-15 summarizes the nationwide cost impacts of the Regulatory Alternatives in the five model plants for the 5-year period following proposal of the Standards. Both capital and annualized costs under Alternative I and II are at a minimum in the small industrial plant due

Table 8-15. NATIONWIDE COST ANALYSIS OF THREE REGULATORY ALTERNATIVES IN FIVE MODEL PLANTS PROJECTED FOR FIVE YEARS AFTER PROPOSAL

	Regulatory Alternative I		Regulatory Alternative II				Regulatory Alternative III[a]			
Model plant category	Total capital cost ($\$10^3$)	Cumulative annualized cost ($\$10^3$)	Total capital cost ($\$10^3$)	Cumulative annualized cost ($\$10^3$)	Cumulative emission reduction[d] (Mg VOC)	Total cost effectiveness[b] $\frac{\Delta\ \$10^3}{\text{Mg VOC}}$	Total capital cost ($\$10^3$)	Cumulative annualized cost ($\$10^3$)	Cumulative emission reduction (Mg VOC)	Total cost effectiveness[b] $\frac{\Delta\ \$10^3}{\text{Mg VOC}}$
Small commercial	385	1,170	385	1,170	e	e	2,250	1,580-1,700	560	0.68-0.72
Medium commercial	2,660	10,800	2,660	10,800	e	e	15,500	9,270-11,200	8,800-12,300	(0.17)[c]-0.03
Large commercial	1,510	5,830	1,510	5,830	e	e	5,520	585-2,270	7,690-10,700	(0.46-0.49)
Small industrial	270	926	270	926	e	e	932	175-413	1,090-1,520	(0.47-0.50)
Large industrial	3,240	7,510	3,240	7,510	e	e	6,720	580-2,800	10,100-14,200	(0.47-0.49)
TOTAL	8,060	26,200	8,060	26,200	e	e	30,900	12,200-18,400	28,200-39,500	(0.28-0.35)

[a] Recovery dryer cooling water is supplied by a refrigerated chiller.

[b] Cost effectiveness defined as the difference between baseline (Alternative I) cumulative annualized cost and that of the given control alternative, per megagram of cumulative VOC emission reduction.

[c] All numbers in parentheses are cost savings.

[d] Regulatory Alternative II emission reductions are not quantifiable.

[e] Not applicable due to unquantifiable emission reductions.

Table 8-16. NATIONWIDE COST ANALYSIS OF THREE REGULATORY ALTERNATIVES IN FIVE MODEL PLANTS PROJECTED FOR TEN YEARS AFTER PROPOSAL

	Regulatory Alternative I		Regulatory Alternative II				Regulatory Alternative III[a]			
Model plant category	Total capital cost ($\$10^3$)	Cumulative annualized cost ($\$10^3$)	Total capital cost ($\$10^3$)	Cumulative annualized cost ($\$10^3$)	Cumulative emission reduction[d] (Mg VOC)	Total cost effectiveness[b] $\frac{\Delta\ \$10^3}{\text{Mg VOC}}$	Total capital cost ($\$10^3$)	Cumulative annualized cost ($\$10^3$)	Cumulative emission reduction (Mg VOC)	Total cost effectiveness[b] $\frac{\Delta\ \$10^3}{\text{Mg VOC}}$
Small commercial	770	4,300	770	4,300	e	e	4,500	5,780-6,230	2,050-2,860	0.68-0.72
Medium commercial	5,310	39,600	5,310	39,600	e	e	31,100	34,000-41,100	32,300-45,000	(0.17)[c]-0.03
Large commercial	3,030	21,400	3,030	21,400	e	e	11,000	2,150-8,320	28,200-39,300	(0.46-0.49)
Small industrial	521	3,400	521	3,400	e	e	1,800	640-1,520	3,990-5,560	(0.47-0.50)
Large industrial	6,660	27,500	6,660	27,500	e	e	13,800	2,120-10,300	37,200-51,900	(0.47-0.49)
TOTAL	16,300	96,200	16,300	96,200	e	e	62,200	44,700-67,500	104,000-145,000	(0.28-0.35)

[a] Recovery dryer cooling water is supplied by a refrigerated chiller.

[b] Cost effectiveness defined as the difference between baseline (Alternative I) cumulative annualized cost and that of the given control alternative, per megagram of cumulative VOC emission reduction.

[c] All numbers in parentheses are cost savings.

[d] Regulatory Alternative II emission reductions are not quantifiable.

[e] Not applicable due to unquantifiable emission reductions.

to low numbers of affected plants (3 additional affected plants per year). The medium commerical plant has the highest nationwide annualized costs as a result of a high rate of additional affected plants added each year (138 per year). Capital costs for Alternative I and II are at a maximum ($3.2 million) in the large industrial plant where the combination of high capital cost and large numbers of additional affected plants results in increased expenditures on equipment.

Regulatory Alternative III nationwide fifth-year capital and annualized costs are at a maximum in the medium commercial plant. Minimum annualized costs, however, occur in the small industrial plant where a high throughput results in a maximum savings of $750,000 through the fifth year. The maximum range of cost effectiveness is found in the small industrial plant where savings of $470 to $500 per megagram of emission reduction result by the fifth year. In contrast, the small commercial plant experiences a cost ranging from $680 to $720 expended per megagram of emission reduction through the fifth year.

Nationwide cost impacts of the Regulatory Alternatives over 10 years following proposal of the standard are tabulated in Table 8-16 for the five model plants. Capital and annualized costs for the period are similar to those of Table 8-15, with the medium commercial plant having the highest range of Alternative I and II annualized costs ($39.6 million) and the large industrial plant having the highest Alternative I and II capital cost ($6.7 million).

Both capital and annualized costs are at their maximum in the medium commercial plant under Alternative III. Annualized cost savings from baseline are at a minimum of $25.4 million in the large industrial plant, where VOC emission reductions reach their maximum range of 37,200 megagrams to 51,900 megagrams over 10 years. In contrast, emission reductions for the period are at their minimum range of 2,050 to 2,850 in the small commercial plant. Lastly, the cost effectiveness of Regulatory Alternative III in the five model plants for 10 years is equivalent to the cost effectiveness of Alternative III over 5 years, with maximum savings of $500 per megagram of emission reduction occurring in the small industrial plant and a maximum cost of $720 expended per megagram of VOC emission reduction in the small commercial plant.

8.4 OTHER COST CONSIDERATIONS

The cost considerations of this section, other than the cost of air pollution control mandated by the proposed standards, are those associated with safety of the plant and its personnel and the discharge of solvent to public waterways, public sewers or adjoining property. Safety of plant and personnel encompasses both fire prevention and the minimization of solvent vapor concentrations that may present a health hazard to plant personnel. Thus, additional cost considerations would be limited to those imposed by the Occupational Safety and Health Administration (OSHA) and the National Fire Protection Association (NFPA).

8.4.1 Control Costs Related To OSHA and NFPA Regulations

OSHA limits the maximum concentration of petroleum solvent vapors to which plant personnel may be exposed to 500 ppm threshold limit value (TLV) (OSHA, 1979). Dry cleaning areas or rooms are required to have a ventilation system independent of the ventilation system for other sections of the plant. This ventilation system usually consists of a fan (with non-ferrous blades) located in or near the roof and a network of ducts with the fan motor installed outside of the duct. The ventilation system must be capable of exhausting one cubic foot per square foot of floor area from the dry cleaning room to a safe outdoor location. Dry cleaning equipment is required to have nameplates that describe the type of solvent used, and dry cleaning dryers are required to have an internal ventilation system that is actuated when the door to the dryer is opened to prevent solvent vapors from escaping into the room.

Under NFPA provisions, dry cleaning equipment and boilers are located in separate rooms, apart from other dry cleaning operations (NFPA, 1979). The walls or partitions of the rooms in which the dry cleaning equipment and boiler are contained must be designed with a fire resistance rating of not less than two hours. Dry cleaning equipment is required to have explosion proof motors and wiring. All electrical equipment and wiring in rooms or areas containing the boiler and dry cleaning equipment are also required to comply with the provisions of the National Electric Codes.

OSHA and NFPA requirements are normally designed into the plant and dry cleaning equipment before their construction. (The model plant costs given in Tables 8-2 to 8-6 include OSHA and NFPA requirements.) Regulatory alternative costs associated with OSHA and NFPA requirements above those normally incurred by a dry cleaning plant are therefore likely to be minimal. However, it is probable that explosion relief ducts may be necessary in plants that use recovery dryers to direct the pressure of an explosion out of the plant to reduce the potential for injury to plant personnel or property. Because the need for such a duct system has not been established, costs associated with purchase and installation of the system have not been evaluated.

8.4.2 Costs Related To Water Pollution Regulations

Water pollution in a petroleum dry cleaning plant is more likely to occur in water wash operations than in dry cleaning operations (see Chapter 7 for water pollution impacts). Solvent carry-over into water that may be disposed via a public sewer system primarily originates from the gravimetric (water/solvent separator) separation of water and solvent from vacuum still and recovery dryer operations. A maximum of 100 parts of solvent per million by volume can be dissolved in water, resulting in the discharge of about 35 kilograms of solvent nationwide in public sewers per year (Saary, 1981). Periodic cleaning and maintenance of the water/solvent separator, without any addition control equipment, is all that is required to optimize the water/solvent separation efficiency. The maintenance of the water/solvent separator is incorporated in the maintenance requirements of the vacuum still and recovery dryer without an additional cost impact.

A network of floor drains connected to an underground dump tank is another requirement of NFPA for accidental solvent spills within the dry cleaning area. The cost of this drainage system is factored into the construction cost of the facility. Therefore, there are no direct costs for water pollution controls in petroleum dry cleaning operations and the volume of solvent disposed is expected to be within the guideline of the Clean Water Act. Also, it is unlikely that any additional federal regulations on effluent discharges for dry cleaning plants will be implemented according to a District Court Ruling (NRDC v. Costle, 1979).

8.4.3 Costs Related To Solid Waste Disposal

The Resource Conservation and Recovery Act (RCRA) sets guidelines for the disposal of toxic and hazardous waste. Under RCRA, special requirements exist for hazardous waste generated by small quantity generators. If a person generates, in a calendar month, a total of less than 1,000 kilograms of hazardous wastes, those wastes are not subject to RCRA requirements (*Federal Register*, 1981). Petroleum dry cleaning plants are exempted from RCRA requirements because they generate less than 1,000 kilograms of waste per month (assuming the weight of solvent only) based on model plant parameters. To defray or eliminate disposal costs for still waste or other solvent-containing waste, many dry cleaners sell waste solvent to solvent treatment companies or use it as a supplemental boiler fuel (Sluizer, 1981; Morris, 1980).

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9. ECONOMIC ANALYSIS

Chapter 9 examines the potential economic impacts of NSPS for petroleum dry cleaning. Economic characteristics of the dry cleaning industry are profiled in Section 9.1. Potential impacts on dry cleaners, suppliers, prices of dry cleaning, employment, trade, and other concerns are assessed in Section 9.2. Aggregate costs and socioeconomic impacts are assessed in Section 9.3. Several points are introduced below (and explained subsequently in greater detail) to provide an overview of the economic analysis.

A model plant approach is used to project pro forma financial conditions at commercial and industrial dry cleaners. Dry cleaners are characterized by five model plants. The impacts of proposed standards requiring dry cleaners to use petroleum recovery dryers (Alternative III), in particular, are measured for each model plant in relation to the costs involved in the use of conventional dryers (the baseline, Alternative I). Conventional dryers have low capital costs but allow substantial quantities of petroleum solvent to be lost; recovery dryers have higher investment costs but use less solvent and have lower operating costs.

Because lost petroleum solvent is expensive, control equipment and practices that conserve solvent offer the potential for net cost savings at some plants. The impacts of standards vary especially in relation to plant size, with larger plants being able to use the recovery equipment more economically. Because there are cost credits from solvent recovery, in many instances there would be little or no cost pressure on dry cleaners' prices from controlling solvent emissions.

The analysis focuses upon replacements of dryers; most outlays associated with the standards and most affected facilities would involve replacements of existing equipment at dry cleaners already using petroleum.

In this chapter, dollars are expressed in first quarter 1981 values, except as noted.

Control costs used in the economic analysis reflect the engineering assumptions described in Chapter 8 but involve a number of specifications and a range of capital cost assumptions. In Chapter 9, it is assumed that refrigerated chillers are needed at each plant (a conservative assumption, since not all plants may need chillers, which add $2,900 to investment requirements at medium commercial plants, for example) and that solvent is recovered at the mid-point of the ranges presented in Tables 8-9 through 8-13.

A range of capital costs is assumed in the economic analysis to model the contingency that some dry cleaners, being small businesses, may have higher than normal capital costs. Bank sources, for example, indicated that loans for equipment financing would need to be repaid in a period of approximately five years (Bray, 1982; McCracken, 1982; Shaw, 1982) even though equipment may have a useful life of 20, 30, or more years. The need to repay loans rapidly could increase the annual capital charges for dry cleaners, so capital costs were calculated with two assumptions: a 10 percent real interest rate and 30 year amortization period (as used in Tables 8-9 through 8-13) and a 10 percent real interest rate but 5 year amortization period. The latter results in a real capital charge of 26.4 percent annually, a high assumption that probably overstates the capital costs for pollution control equipment. While both cost assumptions are presented in the economic analysis, the more stringent 26.4 percent capital cost generally is used to make determinations on economic impacts. Dry cleaners having lower capital costs would have lesser impacts.

9.1 INDUSTRY CHARACTERIZATION

9.1.1 Dry Cleaning Plants

Table 9-1 lists and describes the kinds of firms in the cleaning industry. Using Census Bureau classifications, there are nine kinds of firms, based on primary lines of business. In practice, many cleaners are diversified into several markets, cleaning processes, and related fields like tailoring. It is not uncommon to find firms that have both dry cleaning and laundry operations or, in some cases, both petroleum and perchloroethylene dry cleaning equipment. Among commercial dry cleaners,

Table 9-1. KINDS OF CLEANING FIRMS, AS CLASSIFIED BY THE CENSUS BUREAU[a]

SIC industry number	Title	Primary business
7211	Power laundries, family and commercial	Mechanical laundries using steam or other power.
7212	Garment pressing, and agents for laundries and dry cleaners	Laundry and dry cleaning services but do not do their own cleaning. May do pressing and finishing.
7213	Linen supply	Supply to institutions or households, on a rental basis, linens, towels, and certain garments.
7214	Diaper service	Supply diapers and baby linens to homes, often on a contract basis.
7215	Coin-operated laundries and dry cleaners	Coin-operated or other self-service laundries or dry cleaners.
7216	Dry cleaning plants, except rug cleaning	Dry cleaning or dyeing, other than rugs. For households. Press shops and agents are not included.
7215	Carpet and upholstery cleaning	Carpet or upholstery cleaning, in-plant or on customers' premises.
7218	Industrial launderers	Supply laundered or dry cleaned work uniforms and garments, often on a rental basis.
7219	Laundry and garment services, not elsewhere classified	Other laundry services, including repairing, altering, and storing clothes for individuals, as well as hand laundries.

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[a] Some cleaners are classified elsewhere. Captive cleaning services are reported under the institutions served. All classifications are based upon the primary business activity, regardless of diversification into secondary lines of business (Executive Office of the President. OMB, 1972).

a fraction of plant revenues often come from related lines of business like drapery, leather, or carpet cleaning, tailoring, or laundry (U.S. Bureau of the Census, 1981). Among industrial dry cleaners, it is common that at least 50 percent of cleaning volume is done by laundering; many industrial cleaners launder 80, or even 100, percent of their throughput (U.S. Bureau of the Census, 1981; Rosenthal, 1981a).

Petroleum solvent dry cleaning is one method of dry cleaning garments. Other methods of dry cleaning use perchloroethylene or trichlorofluoroethane solvents. In addition, laundering and specialty cleaning processes also are used in the cleaning industry. This profile of the dry cleaning industry focuses on petroleum dry cleaning plants while also covering trends in the general dry cleaning and laundry industries that reflect trends for petroleum dry cleaning.

Two kinds of plants are common in the dry cleaning industry: commercial plants (also known as retail plants) and industrial plants (also known as textile rental service plants). Commercial plants generally are small and clean garments owned by the public, particularly households. Industrial plants are larger, serve institutional customers, and rent cleaned garments to customers. In some cases, plants serve a mix of retail and industrial or institutional customers.

In the U.S., approximately 25,000 plants provide dry cleaning services (Woolsey, 1980). Of these, approximately 24 percent (about 6,000 plants) use petroleum dry cleaning (Woolsey, 1980). At one time, virtually all commercial dry cleaners used petroleum solvent, but today only a minority do so. The majority of existing commercial dry cleaners use perchloroethylene. Perchloroethylene is a halogenated chemical without the flammability problems of petroleum solvent and, therefore, has been adopted by almost all new commercial dry cleaners established in recent years (Fisher, 1980a). Notwithstanding their gradual decrease in numbers, petroleum dry cleaners continue to account for a substantial share of total dry cleaning volume. Fluorocarbon, the third solvent type, is used by few plants (International Fabricare Institute, 1975).

Approximately 40 percent of all industrial cleaners with dry cleaning equipment use petroleum solvent (Sluizer, 1980a). Industrial cleaners are better able than commercial dry cleaners to install the necessary fireproofing for a new petroleum facility than are commercial plants (Godfrey, 1980). Petroleum solvent is preferred for certain cleaning applications, such as leather cleaning, because it causes less damage to garments than does perchloroethylene (Fisher, 1980a). In both sectors, petroleum and perchloroethylene dry cleaning use different washing and drying equipment; the solvents cannot be used interchangeably in the same equipment.

Two Census Bureau classifications are most representative of petroleum dry cleaners. The commercial dry cleaning sector is represented by SIC 7216 and the industrial cleaning sector by SIC 7218. Again, it is necessary to note that some operations within each classification include non-dry cleaning or non-petroleum dry cleaning operations; some petroleum dry cleaning also takes place in other sectors. In particular, the linen supply industry (SIC 7213) has diversified to the point where it shares many of the characteristics of industrial cleaning and includes many petroleum dry cleaning facilities (Siu, 1980).

9.1.1.1 Commercial Sector. As noted, in 1981, there were approximately 25,000 commercial dry cleaners in the U.S. (Woolsey, 1980). Of these, approximately 6,000 use petroleum solvent (Woolsey, 1980).

The commercial dry cleaning industry has had periods of growth and consolidation, as shown in Table 9-2. Using SIC 7216 as a proxy for the commercial sector, the number of plants in SIC 7216 increased from 26,000 in 1954 to 32,000 in 1963 and dropped recently to 22,000. Demand for dry cleaning dropped in real terms during the mid-1970's, in large part because the public adopted easy-care polyester garments in lieu of garments made of fabrics needing dry cleaning.

Since the late 1970's, however, dry cleaning demand has recovered slightly and reached a plateau. Little or no real growth is projected for the near future. Profitability has recovered to a point of general stability; many of the less well- managed firms already have left the industry (Woolsey, 1980). Unexpected changes in consumer fashions, income, leisure time, work patterns for women, and population growth could influence future revenues (Fisher, 1980b).

Most dry cleaners are small businesses. Family or sole proprietor businesses are common. More than half the commercial dry cleaners employ fewer than five employees (see Table 9-3).

Table 9-2. PLANT AND REVENUE TRENDS IN THE COMMERCIAL SECTOR OF THE DRY CLEANING INDUSTRY (SIC 7216)
(revenues in millions of first quarter 1981 dollars)

Year	Number of plants	Revenues
1954[a]	26,287	3,531
1963[b]	31,722	4,086
1967[c]	30,625	4,882
1972[d]	28,422	3,765
1977[e]	21,868	2,796

[a] U.S. Bureau of the Census, 1957.
[b] U.S. Bureau of the Census, 1966.
[c] U.S. Bureau of the Census, 1972.
[d] U.S. Bureau of the Census, 1975.
[e] U.S. Bureau of the Census, 1980a.

Table 9-3. DISTRIBUTION OF COMMERCIAL DRY CLEANERS (SIC 7216) BY NUMBER OF EMPLOYEES, 1977[a]

Number of employees per plant	Number of plants
0 to 4	11,272
5 to 9	5,627
10 to 19	2,458
20 to 49	741
50 to 99	97
100 or more	23
All sizes	21,868[b]

[a] U.S. Bureau of the Census, 1980a.

[b] Numbers do not sum because not all plants in SIC 7216 are included in the size distribution.

9.1.1.2 Industrial Sector. The industrial sector has fewer plants than the commercial sector. There are more than 1,000 industrial cleaners (U.S. Bureau of the Census, 1980a), of which 230 use petroleum solvent (Faig, 1980). There has been only slight growth in the number of industrial cleaners, (SIC 7218) between 1972 and 1977 (see Table 9-4). For the same timeframe growth in revenues, in real terms, has been less than 0.1 percent. Although the industrial sector's growth has been very slow, it contrasts with the large decline in revenues among commercial dry cleaners.

Compared to commercial dry cleaners, industrial cleaners are much larger and employ more workers per plant. Under 15 percent of industrial cleaners employ fewer than five workers. Most industrial plants employ 10 to 100 workers (see Table 9-5).

9.1.2 Supplier Industries

A number of firms supply petroleum solvent and equipment for the petroleum dry cleaning industry. Tables 9-6 through 9-8 show producers of: petroleum solvent; washers and dryers; and filters and stills, respectively.

Petroleum solvent is a refined petroleum product, similar to kerosene. Solvent is produced at refineries in the U.S. by oil and chemical companies. Refineries, to an extent, can alter their product mixes to produce more or less petroleum solvent depending on the relative market prices for petroleum solvent and other petroleum products.

Because the number of dry cleaners using petroleum solvent has decreased over the last two decades, the replacement market for equipment has declined. There is virtually no market for new petroleum installations, and the number of firms manufacturing petroleum washers and dryers also has declined. The only new entrant in recent years has been a firm that produces petroleum recovery dryers. Recovery dryers are a growth segment within the petroleum equipment market.

Some filters and other equipment used by petroleum dry cleaners are the same as those used by perchloroethylene dry cleaners. Partly as a result, more firms produce filters than produce petroleum washers or dryers. Diversification into general dry cleaning, finishing, laundry, and specialty equipment is common among dry cleaning equipment manufacturers.

Table 9-4. PLANT AND REVENUE TRENDS IN THE INDUSTRIAL LAUNDRY AND DRY CLEANING SECTOR (SIC 7218)[a]
(revenues in millions of first quarter 1981 dollars)

Year	Number of plants	Revenues
1972	1,020	1,674
1977	1,054	1,692

[a] U.S. Bureau of the Census, 1975 and 1980a.

Table 9-5. DISTRIBUTION OF INDUSTRIAL CLEANERS (SIC 7218) BY NUMBER OF EMPLOYEES, 1977[a]

Number of employees per plant	Number of plants
0 to 4	119
5 to 9	97
10 to 19	134
20 to 49	333
50 to 99	215
100 or more	106
All sizes	1,054[b]

[a] U.S. Bureau of the Census, 1980a.

[b] Numbers do not sum because not all plants in SIC 7218 are included in the size distribution.

Table 9-6. PRODUCERS OF PETROLEUM SOLVENT[a]

Company
Amato Solvents
Amoco
ARCO Petroleum Products Company, Division of Atlantic Richfield Company
Ashland Chemical Company, Industrial Chemicals and Solvents Division
CPS Chemical Company
Charter Chemicals, Charter International Oil Company
Coastal States Marketing Inc.
Conoco Chemicals Company, Division of Conoco Inc.
Crowley Chemical Company
Crowley Tar Products Company, Inc.
E.I Du Pont de Nemours and Company, Chemicals, Dyes, and Pigments Department
Exxon Chemicals Company, U.S.A
Ferro Corporation, Productol Chemicals Division
GAF Corporation
Getty Refining and Marketing Company
Grow Group, Inc.
Inland Leidy
Kendall/Amalie, Division of Witco Chemicals Corporation
Kerr-McGee Refining Company
Magic Brothers Oil Company
A. Margolis & Sons Corporation
Neville Chemicals Company
Northwest Petrochemicals Corporation
Octagon Process, Inc.
Phillips Chemical Company
Quaker Oats Company, Chemicals Division
Shell Chemicals Company, Chemical Sales
Sun Petroleum Products Company
Tenneco Oil Company
Texaco Chemicals Company
Union Chemicals Division, Union Oil Company of California
U.S. Petrochemical Company, Inc.

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[a] Chemical Week, 1980; International Fabricare Institute, 1980a.

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Table 9-7. MANUFACTURERS OF PETROLEUM WASHERS AND DRYERS[a]

Manufacturer	Types of equipment
American Laundry	Conventional dryers, 45 kilograms (100 pounds)
Cissell	Conventional dryers, 23 and 50 kilograms (50 and 110 pounds)
Four State	Washers, 14, 18, 27, 36, 45, 68, 91, and 136 kilograms (30, 40, 60, 80, 100, 200, and 300 pounds)
Hoyt Mfg.	Recovery dryers, 23 and 45 kilograms (50 and 100 pounds)
Marvell	Washers for commercial dry cleaners, 14, 20, 27, and 45 kilograms (30, 45, 60, and 100 pounds)
Washex	Washers for industrial and commercial dry cleaners, 45, 113, and 227 kilograms (100, 250, and 500 pounds)

[a] These firms also manufacture other kinds of equipment (Orton, 1981; Rosenthal, 1981a; Sluizer, 1980b; Jenkins, 1981).

Table 9-8. MANUFACTURERS OF STILLS AND FILTERS[a]

Manufacturer (location)	Kinds of affected equipment manufactured
Adco (Sedalia, MO)	Filters
American Laundry Machinery (Cincinnati, OH)	Filters, stills
Caled Signal Chemical (Teterboro, NJ)	Filters
DC Filter and Chemical, Inc. (Sandusky, OH)	Filters
Fabritec, International (Cincinnati, OH)	Stills
Kleen-Rite, Inc. (St. Louis, MO)	Filters
MagiCool Corporation (Sandusky, OH)	Filters
Marvel Manufacturing Company of Canada, Ltd. (Montreal, Quebec, Canada)	Stills
Miracle Core Chemical Industries, Inc. (Cornwell Heights, PA)	Filters
R.R. Street & Company, Inc. (Oak Brook, IL)	Filters, stills
VIC Manufacturing Company (Minneapolis, MN)	Filters, stills
Washex Machinery Corporation (Wichita Falls, TX)	Filters, stills

[a] Cissel, 1981; Marvel, 1981; Miracle Core, 1981; Adco, 1981; Hoyt, 1981; VIC, 1981; American, 1981a; American, 1981b; MagiCool, 1980; DC Filter, 1981; Kleen-Rite, 1981; R.R. Street, 1981; Fabritec, 1981; Caled Signal, 1981; Detrex, 1981; Four State, 1981; Rosenthal, 1981b.

Imports are not a significant factor in the supplier industries for the petroleum dry cleaning industry. While there are some imports of equipment for dry cleaning, as shown in Section 9.1.6, essentially none is for cleaning with petroleum solvent.

9.1.3 Regional Trends

Dry cleaning is a local business. Local fashions, fire codes, economic trends, and other factors shape the dry cleaning industry in different regions. Regional trends in revenues among commercial and industrial cleaners are shown in Table 9-9.

The most salient regional differences concern the market shares of petroleum dry cleaning in different states (see Table 9-10). The South and Plains regions include a number of states that have higher concentrations of petroleum dry cleaners than the nation as a whole. The Northeast has a lower concentration of petroleum dry cleaners. State and local fire codes have been less restrictive in the South, allowing more dry cleaners to use petroleum solvent (Lester, 1980).

Table 9-10 shows also that the share of dry cleaners using petroleum solvent has decreased markedly since the 1960's. The most recent survey (in 1974) on the extent of petroleum dry cleaning use indicated that approximately 32 percent of commercial dry cleaners were using petroleum solvent (International Fabricare Institute, 1975); the share is approximately 24 percent today (Woolsey, 1980).

9.1.4 Prices

Prices for dry cleaning services have moved in parallel with the consumer price index since 1972, as shown in Table 9-11. The major cost component in dry cleaning operations is labor, accounting for at least half the price charged customers (International Fabricare Institute, 1980b).

Average base prices in the U.S. for major dry cleaned items in 1979 were: \$3.66 for suits; \$3.45 for dresses; \$4.65 for overcoats; and \$1.63 for shirts (in current dollars). Prices charged by different dry cleaners vary considerably, however, from industry averages (American Drycleaner, 1980).

9.1.5 Industry Structure

As noted, the dry cleaning industry is a localized industry with thousands of small-scale, independent operations. Many individual proprie-

Table 9-9. REGIONAL TRENDS IN REVENUES AT COMMERCIAL DRY CLEANERS AND INDUSTRIAL CLEANERS (SIC 7216 AND 7218), 1972-1977[a] (millions of first quarter 1981 dollars)

Region	Revenues at commercial dry cleaners (SIC 7216)		Revenues at industrial cleaners (SIC 7218)	
	1972	1977	1972	1977
Northeast	1,000	640	320	290
North Central	940	680	470	480
South	1,230	930	580	580
West	590	510	300	310
All regions	3,760	2,760	1,670	1,660

[a] U.S. Bureau of the Census, 1976a, 1976b, and 1980b.

Table 9-10. PROPORTIONS OF COMMERCIAL DRY CLEANERS USING PETROLEUM SOLVENT, BY STATE AND REGION, 1963-1974

State and region	Percent of commercial dry cleaners using petroleum solvent[b] 1963[a]	1967[d]	1974[e]
Region I	30	24	22
Connecticut	27	20	
Maine	42	34	
Massachusetts	27	22	
New Hampshire	49	28	
New York	27	23	
Rhode Island	39	35	
Vermont	58	61	
Region II	38	35	35
Delaware	39	29	
District of Columbia	24	16	
Maryland	37	37	
New Jersey	29	26	
Pennsylvania	37	37	
Virginia	53	44	
West Virginia	57	55	
Region III	67	65	36
Alabama	69	64	
Florida	59	54	
Georgia	72	71	
Mississippi	81	83	
North Carolina	67	64	
South Carolina	72	73	
Tennessee	58	58	
Region IV	34	33	27
Indiana	45	43	
Kentucky	50	47	
Michigan	34	35	
Ohio	25	23	

State and region	Percent of commercial dry cleaners using petroleum solvent[b] 1963[c]	1967[d]	1974[e]
Region V	54	52	28
Illinois	52	51	
Iowa	65	64	
Minnesota	40	36	
Nebraska	65	61	
North Dakota	63	68	
South Dakota	70	67	
Wisconsin	54	50	
Region VI	73	74	42
Arkansas	81	82	
Kansas	71	72	
Louisiana	72	72	
Missouri	63	59	
Oklahoma	73	75	
Texas	75	78	
Region VII	44	41	27
Arizona	44	49	
Colorado	41	43	
Idaho	72	67	
Montana	58	60	
Nevada	50	32	
New Mexico	65	67	
Oregon	52	48	
Utah	60	54	
Washington	40	40	
Wyoming	71	67	
Region VIII	30	25	11
Alaska	67	64	
California	29	24	
Hawaii	69	63	
United States	48	46	26[b]

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[a] Regions correspond to International Fabricare Institute districts.

[b] Includes dry cleaners using both petroleum solvent and synthetic solvents like perchloroethylene or fluorocarbon, except in 1974. Figures in 1974 are for plants with one solvent type only. Including plants with both petroleum and perchloroethylene facilities, petroleum's share in 1974, nationally, was 32 percent (International Fabricare Institute, 1975).

[c] U.S. Bureau of the Census, 1966.

[d] U.S. Bureau of the Census, 1970.

[e] International Fabricare Institute, 1975.

Table 9-11. DRY CLEANING AND CONSUMER PRICE INDICES, 1954-1981

Year	Dry cleaning price index	Consumer price index-urban
1954	75.2[a]	80.5[d]
1963	88.6[b]	91.7[d]
1967	100.0[b]	100.0[d]
1972	117.7[b]	125.3[d]
1977	170.8[b]	181.5[d]
1981	251.9[c]	262.9[e]

[a] U.S. Department of Labor, 1964.

[b] Predicasts, 1978.

[c] First quarter 1981. Other years are annual averages. Lamb, 1981.

[d] Executive Office of the President, 1979.

[e] U.S. Department of Commerce, 1981.

tors and families serve local markets. At one time, large factory dry cleaning plants with affiliated pick-up stores were common, but few remain today (Fisher, 1980a).

The cleaning industry as a whole shows little concentration in revenues among its largest industry members. Table 9-12 indicates that the four largest cleaning firms account for 5 percent of industry revenues. Even the fifty largest have only 16 percent of industry revenues.

Franchising is not a major form of organization in the dry cleaning industry. In the combined laundry and dry cleaning industry, only 2,800 outlets belong to franchises. Revenues at such outlets amount to $340 million (see Table 9-13).

9.1.6 Trade

International trade is not an important element in the dry cleaning industry. Dry cleaning service areas are limited by transportation factors and costs.

A 1962 study showed that only 2 percent of the workers in the combined laundry and dry cleaning industry worked in firms receiving 50 percent or more of their revenues from interstate commerce (U.S. Department of Labor, 1962). Although dated, this information indicates clearly that the industry is localized. International commerce is negligible.

Table 9-14 shows U.S. imports of dry cleaning equipment. Imports total approximately $3.3 million, but almost none is petroleum solvent equipment. The majority is perchloroethylene dry cleaning equipment.

9.1.7 Finances

The dry cleaning industry is relatively stable, after a severe recession during the mid-1970's and a moderate upswing at the end of the 1970's. Much of the health of the industry today reflects diversification by dry cleaners into related fields like leather cleaning, rug cleaning, tailoring, and other services (Faig, 1981).

Although there is considerable variety among dry cleaners in their financial condition, a generalized set of income and cost ratios can be constructed. The ratios are based upon arithmetic averages of several data samples and are shown in Table 9-15. Earnings before taxes in relation to revenues average approximately 8.0 percent at commercial plants and 5.6 percent at industrial plants. Depreciation is approximately 3.9 percent of revenues at commercial plants and 2.2 percent at industrial plants.

Table 9-12. CONCENTRATION OF REVENUES AMONG MAJOR FIRMS: COMBINED LAUNDRY, CLEANING, AND OTHER GARMENT SERVICES (SIC 721), 1972[a]
(revenues in millions of first quarter 1981 dollars)

Firms ranked by revenues	Number of plants	Revenues	Revenues as a percent of total
Four largest firms	157	671	5.4
Eight largest firms	251	971	7.8
Twenty largest firms	458	1,411	11.4
Fifty largest firms	624	1,969	15.9
Total industry	97,340	12,413	100.0

[a] U.S. Bureau of the Census, 1975.

Table 9-13. FRANCHISING IN LAUNDRY AND DRY CLEANING SERVICES: DISTRIBUTION BY NUMBER OF PLANTS, 1977
(revenues in millions of first quarter 1981 dollars)

Plants per firm	Number of franchising firms	Number of plants	Revenues
50 or fewer	9	208	25.3
51 or 150	3	192	28.5
151 or more	3	2,369	284.3
All major franchises	15	2,769	338.1

[a] U.S. Department of Commerce (ITA), 1980.

Table 9-14. U.S. IMPORTS OF DRY CLEANING MACHINES, EXCLUDING COINOPERATED MACHINES, 1977[a]
(customs value in thousands of first quarter 1981 dollars)

Country of origin	Dry cleaning machines		Parts for dry cleaning machines	
	Units	Customs value	Units	Customs value
United Kingdom	62	510	-	-
Federal Republic of Germany	158	1,810	-	330
Italy	70	490	-	-
Others	9	80	-	100
All countries	299	2,880	-	430

[a] U.S. Bureau of the Census. 1978.

Table 9-15. INCOME AND COST RATIOS USED AS THE BASIS FOR MODEL PLANT PRO FORMA CASH FLOWS
(percent of plant revenues)

Financial item	Commercial plants	Industrial plants
Revenues	100.0	100.0
Costs (excluding depreciation)	88.1	92.2
Depreciation[a]	3.9[b]	2.2[d]
Earnings before taxes[a]	8.0[c]	5.6[e]

[a] Earnings and depreciation are expressed as percentages of revenues because this is the form used by the data sources.

[b] This is an average of levels from the following data samples: 4.0 percent among laundries and dry cleaners from 1978-1980 (Robert Morris Associates, 1979-1981); 3.3 percent among laundries and dry cleaners in the Southeast from 1977-1979 (Wilson, 1978-1980); and 4.4 percent among commercial dry cleaning package plants from 1977-1979 (International Fabricare Institute, 1978-1980b).

[c] This is an average of levels from the following data samples: 9.5 percent among commercial dry cleaners from 1979-1980, representing after-tax earnings of 7.1 percent increased to allow a 25 percent tax rate (Dun & Bradstreet, 1980-1981): 5.6 percent among laundries and dry cleaners from 1978-1980 (Robert Morris Associates, 1979-1981); 7.4 percent among commercial dry cleaning package plants from 1977-1979 (International Fabricare Institute, 1979-1980b); and 9.6 percent among laundries and dry cleaners from 1976-1979, excluding 1977 (International Fabricare Institute, 1977-1980b).

[d] This figure is derived from linen suppliers and industrial laundries from 1978-1979 in the Textile Rental Services Association of America, whose membership has a product mix of 56 percent linen supply, 39 percent industrial laundry, and 6 percent commercial laundry (Textile Rental Services Association of America, 1980-1980).

[e] This figure represents earnings at industrial laundries from 1979-1980, based on after-tax earnings of 4.2 percent increased to allow a 25 percent tax rate (Dun & Bradstreet, 1980-1981).

(Depreciation and earnings are expressed as percentages of revenues at dry cleaners to allow for comparison among different size plants.)

9.1.8 Affected Facilities

Affected facilities under petroleum NSPS are defined as washers, dryers, filters (housings), stills, and settling tanks. Tables 9-16 through 9-20 project the number of affected facilities of each kind at each type of plant during the first five years after proposal. It is useful to note that although five kinds of affected facilities are projected, only affected dryers would incur additional investment costs under Alternative III.

Affected facilities are projected largely according to expected trends in the rate at which existing equipment will wear out. Few new plants in the dry cleaning industry are expected to use petroleum solvent. An annual growth rate of zero among commercial dry cleaners using petroleum solvent and one percent among industrial cleaners using petroleum solvent is assumed (Faig, 1980). Most affected facilities will be replacements of existing equipment.

Replacements of existing petroleum dry cleaning equipment are projected on the basis of average equipment lifetimes. There is disagreement among industry sources over average equipment lifetimes. Several equipment manufacturers and suppliers indicate that petroleum dry cleaning equipment lasts approximately 15 years (Carruth, 1980; Oakes, 1980; Orton, 1981; Richars, 1981). Others indicate that petroleum dry cleaning equipment lasts approximately 20 years (Godfrey, 1980; Montgomery, 1981). Some sources indicate that petroleum dry cleaning equipment lasts indefinitely and may not wear out (Rosenthal, 1981a).

An average equipment life of 30 years is assumed in this analysis, resulting in an annual replacement rate of 3.3 percent. The 30 year lifetime is longer than many of the estimates given by industry sources. Considerable leeway is possible for individual dry cleaners to delay replacement (Godfrey, 1980; Oakes, 1980); hence, actual replacements in a given year may differ from the trends, but, over time, replacements are expected to approximate the projections based on estimates of average equipment lifetimes. Most replacements of petroleum dry cleaning equipment will be made with new, petroleum dry cleaning equipment. Conversions to perchloroethylene are rare (Montgomery, 1981).

Table 9-16. AFFECTED FACILITIES AT SMALL COMMERCIAL DRY CLEANERS DURING FIRST FIVE YEARS AFTER PROPOSAL[a]

Years after proposal	Recovery dryers[b]	Washers[c]	Filters[c]	Stills[c]	Settling tanks[c]	Total
1	20	20	20	20	20	100
2	20	20	20	20	20	100
3	20	20	20	20	20	100
4	20	20	20	20	20	100
5	20	20	20	20	20	100
1-5	100	100	100	100	100	500

[a] Projections are based on a zero annual growth rate for commercial plants and a replacement rate of 3.3 percent. Each small commercial plant has one washer, filter, dryer, still, and tank. Figures are rounded.

[b] Affected by Alternative III.

[c] Affected by Alternative II or III.

TABLE 9-17. AFFECTED FACILITIES AT MEDIUM COMMERCIAL DRY CLEANERS DURING FIRST FIVE YEARS AFTER PROPOSAL[a]

Years after proposal	Recovery dryers[b]	Washers[c]	Filters[c]	Stills[c]	Settling tanks[c]	Total
1	138	138	138	138	138	690
2	138	138	138	138	138	690
3	138	138	138	138	138	690
4	138	138	138	138	138	690
5	138	138	138	138	138	690
1-5	690	690	690	690	690	3,450

[a] Projections are based on a zero annual growth rate for commercial plants and a replacement rate of 3.3 percent. Each small commercial plant has one washer, filter, dryer, still, and tank. Figures are rounded.

[b] Affected by Alternative III.

[c] Affected by Alternative II or III.

Table 9-18. AFFECTED FACILITIES AT LARGE COMMERCIAL DRY CLEANERS DURING FIRST FIVE YEARS AFTER PROPOSAL[a]

Years after proposal	Recovery dryers[b]	Washers[c]	Filters[c]	Stills[c]	Settling tanks[c]	Total
1	47	47	47	47	47	235
2	47	47	47	47	47	235
3	47	47	47	47	47	235
4	47	47	47	47	47	235
5	47	47	47	47	47	235
1-5	235	235	235	235	235	1,175

[a] Projections are based on a zero annual growth rate for commercial plants and a replacement rate of 3.3 percent. Each small commercial plant has one washer, filter, dryer, still, and tank. Figures are rounded.

[b] Affected by Alternative III.

[c] Affected by Alternative II or III.

Table 9-19. AFFECTED FACILITIES AT SMALL INDUSTRIAL DRY CLEANERS DURING FIRST FIVE YEARS AFTER PROPOSAL[a]

Years after proposal	Recovery dryers[b]	Washers[c]	Filters[c]	Stills[c]	Settling tanks[c]	Total
1	9	3	9	3	3	27
2	9	3	9	3	3	27
3	9	3	9	3	3	27
4	9	3	9	3	3	27
5	9	3	9	3	3	27
1-5	45	15	45	15	15	135

[a] Projections are based on a one percent annual growth rate for industrial plants and a replacement rate of 3.3 percent. Each small industrial plant has one washer, three filters, three dryers, one still, and one tank. Figures are rounded.

[b] Affected by Alternative III.

[c] Affected by Alternative II or III.

Table 9-20. AFFECTED FACILITIES AT LARGE INDUSTRIAL DRY CLEANERS DURING FIRST FIVE YEARS AFTER PROPOSAL[a]

Years after proposal	Recovery dryers[b]	Washers[c]	Filters[c]	Stills[c]	Settling tanks[c]	Total
1	64	16	0	24	8	112
2	64	16	0	24	8	112
3	64	16	0	24	8	112
4	64	16	0	24	8	112
5	64	16	0	24	8	112
1-5	320	80	0	120	40	560

[a] Projections are based on a one percent annual growth rate for industrial plants and a replacement rate of 3.3 percent. Each large industrial plant has two washers, no filters, eight dryers, three stills, and one tank. Figures are rounded.

[b] Affected by Alternative III.

[c] Affected by Alternative II or III.

At small commercial cleaners, approximately 500 facilities (i.e., items of equipment) may be affected in the first five years after proposal of the NSPS. In the same period, there may be 3,450 affected facilities at medium commercial dry cleaners, 1,175 at large commercial dry cleaners, 135 at small industrial cleaners, and 560 at large industrial cleaners. The sizes of facilities (equipment) affected at each type of plant differ, reflecting the plant parameters identified in Chapter 8 for each model plant type. The total number of affected facilities of all types may be approximately 5,820 during the first five years after proposal.

The number of different plants affected will be less than the number of affected facilities. Each plant may have more than one affected facility (e.g., a dryer and a still may be replaced). The cost figures used in the economic analysis refer to plants that replace dryers, since recovery dryers are the major cost items under Regulatory Alternative III. The number of dry cleaning plants with affected dryers may total: 100 small commercial plants; 690 medium commercial plants; 235 large commercial plants; 15 small industrial plants; and 40 large industrial plants. Costs for affected items other than dryers generally are the same as in the baseline, such that while emissions may be controlled at the other facilities the industry would not be incuring extra costs.

9.2 ECONOMIC IMPACT OF REGULATORY ALTERNATIVES

This section examines the economic impacts of NSPS for petroleum dry cleaning. Two points are evident in the economic impact analysis. First, the NSPS generally would not affect the price or availability of dry cleaning services. Production costs would increase only slightly, and in many cases would decrease, if dry cleaners recovered solvent instead of venting it. Only small commercial plants (if not exempted) would have sizeable cost increases.

Second, large plants in the industry would be able to finance the emissions control equipment, but very small plants would not. The ability of dry cleaners to purchase recovery dryers is largely a function of the size of their revenues. Large commercial, small industrial, and large industrial plants would be able to finance Alternative III equipment costs from internal cash flow or debt financing. On the other hand, small commercial plants might lose 90 percent of their earnings and probably would not be able to obtain loans for recovery dryers. Medium commercial plants generally would be able to finance emissions control equipment but would experience a 2 percent net increase in production costs, and in some cases may have difficulties obtaining financing.

Because the economics of operating recovery dryers varies with plants' scale of dry cleaning throughput, a breakeven throughput level can be identified to indicate the plant size at which recovery dryers would incur costs no greater than those for conventional dryers. As explained later, this breakeven level is estimated to take place at 59,940 kilograms (132,170 pounds) per year of dry cleaning.

9.2.1 Economic Impact Assessment Methodology

Economic impacts are examined using model plants under three different regulatory scenarios. Alternative I represents the baseline and assumes the use of petroleum dry cleaning equipment using existing technologies. Alternative II resembles Alternative I, but also would require dry cleaners to follow good housekeeping practices. Because Alternative II is similar to Alternative I, there would be only slight changes in the economic effects on the industry. Alternative III, though, requires the adoption of recovery dryers at a sizable expense. Economic characteristics of plants under Alternative III, therefore, would exhibit a distinct change from those of the baseline.

If small plants were exempted, price increases and cost pass-through would not be key issues for this standard. For most model plants, the control techniques would generate net savings even after accounting for annualized capital recovery charges. The primary issue in the analysis is whether dry cleaners can afford to adopt the pollution control technologies, particularly recovery dryers, which cost approximately $23,000 each (see Chapter 8). Dry cleaners generally are small businesses with limited funds.

Financial feasibility is related closely to plant size, in terms of annual throughput. In general, smaller plants would find control requirements more difficult to finance than would larger plants. Pro forma projections for five model plants are constructed to measure capital requirements in relation to various indices of financial resources for plants of different sizes.

Three financial indicators are used in the analysis. These are: net annualized costs compared to the baseline; the ratio of annual internal cash flow (depreciation plus after-tax earnings) to the capital requirements of the standard; and the interest coverage ratio if control investments are financed entirely by debt. The exact methodology is explained in Section 9.2.4.

One test not employed in this analysis is the extent to which capitalization ratios could be changed. Capitalization ratios of model plants are not examined for three reasons. First, it is difficult to establish threshold levels showing which debt-to-equity ratios represent the limits of financial acceptability. Bankers tolerate wide variation in capitalization ratios because they examine many factors in arriving at credit determinations. Second, dry cleaners often have widely varying capital ratios. There is no clear consensus among data sources as to the average capitalization mix for dry cleaners. Finally, interest coverage is a concept that more directly relates use of debt to the riskiness of firms. By examining interest coverage, capitalization structures are considered implicitly.

Plants of different sizes are assessed for their ability to finance pollution control outlays. Because the analysis uses model plants, caution must be taken in interpreting the results to allow for variations among actual dry cleaners in each of the size categories.

After financial feasibility is determined, other ramifications of the standards are examined. These include employment effects, international trade, and small business aspects. One of the distinctive characteristics of the dry cleaning industry is that it is composed almost entirely of small businesses. The requirements of the Regulatory Flexibility Act are addressed and the financial tests reflect, in part, the characteristics of small business finances.

Throughout the analysis, costs and impacts are computed as a range bounded by two sets of assumptions. In one case, capital costs for affected facilities are calculated at a 10 percent real interest rate and 30 year amortization period (as used frequently by EPA and presented in Chapter 8). In the other case, the same interest rate is used but a five year period is assumed for amortization of investments. Ten percent is a real rate of interest and corresponds to nominal rates of 19 or 20 percent if compounded by an inflation rate of eight or nine percent.

9.2.2 Affected Facilities/Modifications and Reconstructions

As shown in Section 9.1, emission standards for the petroleum dry cleaning industry will affect equipment replacements rather than new plants. Perchloroethylene, rather than petroleum, is the preferred solvent for new plants today. Petroleum equipment is sold primarily for replacements at established plants. Accordingly, impacts are addressed in terms of existing dry cleaners that replace equipment.

Reconstructions and modifications will not be major impact areas for a petroleum dry cleaning NSPS. Filters generally are not reconstructed because housings are simple units without moving parts. Dryers are more complex and expensive. Repairs and reconstructions of dryers can be expected but, according to trade sources, would not approach 50 percent of the cost of a new dryer (Carruth, 1980; Nieckula, 1981). Accordingly, such reconstructions would not result in affected facilities under the definition used in the NSPS.

Modifications also are unlikely, except in the case of solvent switching from petroleum to perchloroethylene. Modifications to use perchloroethylene would be accomplished in most instances by complete replacement of petroleum washer and dryer units with perchloroethylene units, which would be expensive.

9.2.3. Price Impacts

Major price increases are unlikely to result from any of the alternative levels for two reasons. First, the NSPS will affect very few facilities in the industry. The number of affected facilities each year is only a small fraction of the petroleum dry cleaning industry, which in turn accounts for only one quarter of commercial dry cleaning and one half of industrial dry cleaning. As a result, most affected firms would not raise prices. Affected firms would have to compete against perchloroethylene dry cleaners and other petroleum dry cleaners not affected by these standards.

Second, for most model plant types, the standards would actually decrease production costs compared to the baseline. Solvent recovery provides credits which offset higher capital charges. Net production costs, even with Alternative III control requirements, decrease at three of the five model plants: large commercial, small industrial, and large industrial plants. These changes are shown in Table 9-21.

Table 9-21. DIFFERENTIAL COST IMPACTS AMONG PLANTS OF DIFFERENT SIZES: ALTERNATIVE III REQUIREMENTS[a]
(first quarter 1981 dollars)

Cost impact item	Small commercial plant	Medium commercial plant	Large commercial plant	Small industrial plant	Large industrial plant
Cost increase (decrease) from the baseline due to Alternative III ($$10^3$)	4.4	2.7	(3.6)	(6.6)	(34.1)
Dry cleaning revenues ($$10^3$)	52.5[b]	122.5[b]	315.0[b]	340.0[c]	1,190.0[c]
Cost increase (decrease) as a percentage of dry cleaning revenues	8	2	(1)	(2)	(3)
Cost increase (decrease) per kilogram of dry cleaned garments ($)	0.31	0.08	(0.04)	(0.04)	(0.05)
Cost increase (decrease) per pound of dry cleaned garments ($)	0.15	0.04	(0.02)	(0.02)	(0.02)

[a] Costs are based on a real interest rate of 10 percent and an equipment amortization period of five years. This is the high cost assumption.

[b] Commercial dry cleaning model plant revenues reflect model plant throughput volumes at $3.86 per kg ($1.75 per pound) in the commercial sector. This figure reflects the approximate composite of several sources (Donaldson, 1982; Hranicky, 1982; Platt, 1982; Rechnitz, 1981).

[c] Industrial dry cleaning model plant revenues reflect model plant throughput volumes at $1.87 per kg ($0.85 per pound) in the industrial sector (Sluizer, 1981).

Net production costs at small commercial plants would increase $4,400 -- roughly 8 percent of dry cleaning revenues or $0.31 per kilogram ($0.15 per pound) of garments cleaned, assuming investments are amortized over five years. Medium commercial plants show a 2 percent cost increase in relation to dry cleaning revenues, assuming a five year amortization period.

Small commercial plants would have difficulties both financing Alternative III control equipment (see section 9.2.4) and surviving with the added production costs due to pollution control. Small commercial plants would face an increase in production costs equal to 8 percent of revenues -- essentially equal to their existing profit margin (as shown earlier in Table 9-15). Some small commercial plants could raise prices if they served a high-quality or geographically isolated segment of the market. Others, however, would not be able to raise prices because of competition from unaffected plants and medium commercial plants in the same area that did not face similar levels of cost increases. The small commercial plants in competitive markets, therefore, would find their profitability eliminated.

For consumers, isolated price increases of up to 8 percent are possible at small commercial plants if no exemption is made for small plants. However, given that small commercial plants number only 600 among the 6,150 commercial dry cleaners using petroleum solvent (and an even smaller fraction of total commercial dry cleaners), it is likely that these firms would not set the price for most users of dry cleaning services. The overall cost to consumers of commercial dry cleaning would remain largely unchanged, with isolated exceptions for special markets served by small plants.

Pressures on prices would be slight (2 percent) among medium commercial plants and non-existent among large commercial plants or industrial model plants. Alternative II, it may be noted, would cause no pressures for price increases at any model plant, since costs would be less than, or equal to, costs in the baseline.

9.2.4 Financial Feasibility

The ability of dry cleaners to finance purchases of recovery dryers and conventional dryers is discussed below.

9.2.4.1 Model Plant Pro Formas. Model plant finances are shown on a pro forma basis in Tables 9-22 through 9-28. Table 9-22 shows revenues from dry cleaning and other operations. These range from $62,000 per year at small commercial model plants to $2,380,000 per year at large industrial model plants. Table 9-23 shows internal cash flow at each of the five model plants. Internal cash flow is defined as depreciation plus after-tax earnings. These items are estimated as percentages of plant revenues because this is the form most commonly used in data sources from which the percentages were obtained. The financial parameters used in the pro formas are presented in Section 9.1.

As shown in Table 9-23, internal cash flows from operations range from $6,300 at small commercial plants to $137,400 at large industrial plants. These figures represent average cash flows for firms of model plant sizes. Tables 9-24 through 9-28 show how capital requirements for the three regulatory alternatives relate to the financial characteristics of each of the five model plants. Each table presents data for a different model plant, using a real interest rate of 10 percent and a range of amortization periods from five to 30 years in the capital recovery factors. The tables assume no pass-through of any cost increases due to the NSPS.

9.2.4.2 Financial Feasibility Indicators. Model plants are used to assess the financial feasibility of compliance with regulatory alternatives for the standards. Several issues are addressed in particular by the analysis: the effects of regulatory alternatives upon the earnings of dry cleaners; the ability of dry cleaners to purchase control equipment from internal resources; and the ability of dry cleaners to borrow funds to finance purchases of recovery dryers.

The first issue is addressed by comparing the increased annualized capital charges for owning required equipment against the recovery credits for solvent (and, in some cases, steam) saved. Net annualized costs for each regulatory alternative at model plants indicate the extent to which dry cleaners would experience decreases in earnings as a result of standards.

The ability of dry cleaners to purchase recovery dryers depends upon the availability of internal financial resources (depreciation and after-tax earnings) and external credit from banks. Since firms normally base

Table 9-22. SELECTED STATISTICS FOR PETROLEUM DRY CLEANING MODEL PLANTS: NUMBER, THROUGHPUT, AND REVENUES, 1981
(first quarter 1981 dollars)

		Dry cleaning throughput per plant		Dry cleaning revenues		Revenues per plant ($$10^3$)		
Model plants	Number	10^3 Kg	(10^3 lb)	$ Per Kg	($ Per lb)	Dry cleaning	Other	Total
Small commercial	600	14.0	(30.0)	3.86[a]	(1.75)[a]	52.5	9.3[c]	61.8
Medium commercial	4,150	32.0	(70.0)	3.86[a]	(1.75)[a]	122.5	21.6[c]	144.1
Large commercial	1,400	82.0	(180.0)	3.86[a]	(1.75)[a]	315.0	55.6[c]	370.6
Small industrial	60	180.0	(400.0)	1.87[b]	(0.85)[b]	340.0	340.0[d]	680.0
Large industrial	170	635.0	(1,400.0)	1.87[b]	(0.85)[b]	1,190.0	1,190.0[d]	2,380.0

[a] Donaldson, 1982; Hranicky, 1982; Platt, 1982; Rechnitz, 1981.

[b] Sluizer, M., 1981.

[c] 15 percent of total revenues are from miscellaneous services (U.S. Bureau of the Census, 1981).

[d] 50 percent of total revenues are from laundry operations.

Table 9-23. MODEL PLANT INTERNAL CASH FLOWS
(thousands of first quarter 1981 dollars)

Model plants	Total plant revenues	Depreciation	Earnings before taxes	Income taxes[e]	Net internal cash flow
Small commercial	61.8	2.4[a]	4.9[c]	(1.0)	6.3
Medium commercial	144.1	5.6[a]	11.5[c]	(2.4)	14.7
Large commercial	370.6	14.5[a]	29.7[c]	(6.4)	37.7
Small industrial	680.0	15.0[b]	38.1[d]	(8.4)	44.7
Large industrial	2,380.0	52.4[b]	133.3[d]	(48.2)	137.4

[a] Depreciation at commercial dry cleaners is assumed to be 3.9 percent of revenues (Robert Morris Associates, 1979-1981; International Fabricare Institute, 1978-1980b; Wilson, 1978-1980). Depreciation is expressed as a percent of revenues, rather than of assets, because this is the form used in the data sources.

[b] Depreciation at industrial cleaners is assumed to be 2.2 percent of revenues (Textile Rental Services Association, 1980). Depreciation is expressed as a percentage of revenues, rather than of assets, because this is the form used in the data sources.

[c] Earnings before taxes are assumed to be 8.0 percent of revenues at commercial dry cleaners (Dun & Bradstreet, 1980-1981; Robert Morris Associates, 1979-1981; International Fabricare Institute, 1977-1980b). No differentiation is made for different size plants because the data sources did not show a consistent pattern relating profits to scale of operations.

[d] Earnings before taxes are assumed to be 5.6 percent of revenues at industrial cleaners (Dun & Bradstreet, 1980-1981).

[e] Income taxes are calculated using the progressive federal corporate schedule. This is 16 percent on the first $25,000 of earnings, 19 percent on the second $25,000, 30 percent on the next $25,000, 40 percent on the next $25,000, and 46 percent thereafter (U.S. Senate, 1980b; U.S. Congress, 1981). A state income tax rate of five percent was added to all rates reflecting a general average of state income tax rates (Council of State Governments, 1980). Parentheses denote items to be subtracted when totaling net internal cash flow.

Table 9-24. FINANCIAL FEASIBILITY INDICATORS FOR SMALL COMMERCIAL PLANTS
(thousands of first quarter 1981 dollars)

Regulatory alternative	Capital requirements	Increase (decrease) in earnings before taxes[a]		Annual cash flow as a percent of capital requirements[b]	Interest coverage ratio if all-debt financed[c]
		Amount	As a percent of baseline		
Assuming a 30-year amortization period[d]					
Alternative I[e]	3.9	-	-	164	3.3
Alternative III[f]	22.5	(1.4)	(29)	28	1.8
Assuming a 5-year amortization period[d]					
Alternative I[e]	3.9	-	-	164	3.3
Alternative III[f]	22.5	(4.4)	(89)	28	1.1

[a] The difference in net annualized cost from the baseline.

[b] Annual cash flow is depreciation plus after-tax earnings from existing operations.

[c] Interest coverage is the ratio of earnings before interest and taxes divided by interest payments. The baseline is assumed to equal the industry average ratio. Industry average ratios are 3.3 among commercial dry cleaners and 3.6 among industrial plants (Robert Morris Associates, 1979-1981).

[d] Assumes a real interest rate of 10 percent.

[e] Alternative I is the baseline. It consists of the replacement of petroleum dryers with equipment of the same conventional type.

[f] Alternative III involves both good housekeeping practices and adoption of recovery dryers. Recovery credits for solvent saved are the midpoints of the ranges presented in Chapter 8.

Table 9-25. FINANCIAL FEASIBILITY INDICATORS FOR MEDIUM COMMERCIAL PLANTS (thousands of first quarter 1981 dollars)

Regulatory alternative	Capital requirements	Increase (decrease) in earnings before taxes[a]		Annual cash flow as a percent of capital requirements[b]	Interest coverage ratio if all-debt financed[c]
		Amount	As a percent of baseline		
Assuming a 30-year amortization period[d]					
Alternative I[e]	3.9	-	-	383	3.3
Alternative III[f]	22.5	0.3	2	65	2.7
Assuming a 5-year amortization period[d]					
Alternative I[e]	3.9	-	-	383	3.3
Alternative III[f]	22.5	(2.7)	(23)	65	1.9

[a] The difference in net annualized cost from the baseline.

[b] Annual cash flow is depreciation plus after-tax earnings from existing operations.

[c] Interest coverage is the ratio of earnings before interest and taxes divided by interest payments. The baseline is assumed to equal the industry average ratio. Industry average ratios are 3.3 among commercial dry cleaners and 3.6 among industrial plants (Robert Morris Associates, 1979-1981).

[d] Assumes a real interest rate of 10 percent.

[e] Alternative I is the baseline. It consists of the replacement of petroleum dryers with equipment of the same conventional type.

[f] Alternative III involves both good housekeeping practices and adoption of recovery dryers. Recovery credits for solvent saved are the midpoints of the ranges presented in Chapter 8.

Table 9-26. FINANCIAL FEASIBILITY INDICATORS FOR LARGE COMMERCIAL PLANTS (thousands of first quarter 1981 dollars)

Regulatory alternative	Capital requirements	Increase (decrease) in earnings before taxes[a]		Annual cash flow as a percent of capital requirements[b]	Interest coverage ratio if all-debt financed[c]
		Amount	As a percent of baseline		
Assuming a 30-year amortization period[d]					
Alternative I[e]	6.4	-	-	586	3.3
Alternative III[f]	23.5	6.3	21	161	3.4
Assuming a 5-year amortization period[d]					
Alternative I[e]	6.4	-	-	586	3.3
Alternative III[f]	23.5	3.6	12	161	2.9

[a] The difference in net annualized cost from the baseline.

[b] Annual cash flow is depreciation plus after-tax earnings from existing operations.

[c] Interest coverage is the ratio of earnings before interest and taxes divided by interest payments. The baseline is assumed to equal the industry average ratio. Industry average ratios are 3.3 among commercial dry cleaners and 3.6 among industrial plants (Robert Morris Associates, 1979-1981).

[d] Assumes a real interest rate of 10 percent.

[e] Alternative I is the baseline. It consists of the replacement of petroleum dryers with equipment of the same conventional type.

[f] Alternative III involves both good housekeeping practices and adoption of recovery dryers. Recovery credits for solvent saved are the midpoints of the ranges presented in Chapter 8.

Table 9-27. FINANCIAL FEASIBILITY INDICATORS FOR SMALL INDUSTRIAL PLANTS (thousands of first quarter 1981 dollars)

Regulatory alternative	Capital requirements	Increase (decrease) in earnings before taxes[a] Amount	As a percent of baseline	Annual cash flow as a percent of capital requirements[b]	Interest coverage ratio if all-debt financed[c]
Assuming a 30-year amortization period[d]					
Alternative I[e]	19.3	-	-	231	3.6
Alternative III[f]	66.6	14.1	37	67	3.7
Assuming a 5-year amortization period[d]					
Alternative I[e]	19.3	-	-	231	3.6
Alternative III[f]	66.6	6.6	17	67	2.6

[a] The difference in net annualized cost from the baseline.

[b] Annual cash flow is depreciation plus after-tax earnings from existing operations.

[c] Interest coverage is the ratio of earnings before interest and taxes divided by interest payments. The baseline is assumed to equal the industry average ratio. Industry average ratios are 3.3 among commercial dry cleaners and 3.6 among industrial plants (Robert Morris Associates, 1979-1981).

[d] Assumes a real interest rate of 10 percent.

[e] Alternative I is the baseline. It consists of the replacement of petroleum dryers with equipment of the same conventional type.

[f] Alternative III involves both good housekeeping practices and adoption of recovery dryers. Recovery credits for solvent saved are the midpoints of the ranges presented in Chapter 8.

Table 9-28. FINANCIAL FEASIBILITY INDICATORS FOR LARGE INDUSTRIAL PLANTS
(thousands of first quarter 1981 dollars)

Regulatory alternative	Capital requirements	Increase (decrease) in earnings before taxes[a]		Annual cash flow as a percent of capital requirements[b]	Interest coverage ratio if all-debt financed[c]
		Amount	As a percent of baseline		
Assuming a 30-year amortization period[d]					
Alternative I[e]	85.3	-	-	161	3.6
Alternative III[f]	176.9	48.5	36.4	78	4.0
Assuming a 5-year amortization period[d]					
Alternative I[e]	85.3	-	-	161	3.6
Alternative III[f]	176.9	34.1	25.5	78	3.2

[a] The difference in net annualized cost from the baseline.

[b] Annual cash flow is depreciation plus after-tax earnings from existing operations.

[c] Interest coverage is the ratio of earnings before interest and taxes divided by interest payments. The baseline is assumed to equal the industry average ratio. Industry average ratios are 3.3 among commercial dry cleaners and 3.6 among industrial plants (Robert Morris Associates, 1979-1981).

[d] Assumes a real interest rate of 10 percent.

[e] Alternative I is the baseline. It consists of the replacement of petroleum dryers with equipment of the same conventional type.

[f] Alternative III involves both good housekeeping practices and adoption of recovery dryers. Recovery credits for solvent saved are the midpoints of the ranges presented in Chapter 8.

annual investment budgets on their annual cash flow from operations (depreciation plus after-tax earnings), the annual cash flow constitutes an appropriate measure of the magnitude of capital requirements of each regulatory alternative. Plants that have annual cash flows lower than required capital outlays would probably need to borrow part, or all, of the amounts for control investments.

The likelihood of bank lending for dry cleaners is assessed by measuring the change in the interest coverage ratio. Interest coverage measures the ratio of earnings before interest and taxes to annual interest payments. Dry cleaners need to maintain a margin of before-tax cash flow in excess of required payments to reassure creditors that payments will be met regularly.

The analysis focuses upon a comparison of Alternative III with the baseline (Alternative I), because Alternative II does not present difficulties for any plants. Alternative II consists of standards requiring better work practices that would reduce solvent losses and, hence, lower production costs. Alternative II resembles the baseline (Alternative I) in assuming dry cleaners adopt conventional equipment, but differs in that operating costs would decrease. While operating costs would decrease, the extent of the decrease is not quantified in the economic analysis, in part because of the variability in savings due to changes only in work practices. Investment requirements would be the same as those in Alternative I, nonetheless, and accordingly the economic analysis for Alternative II can be equated with that shown in this chapter for Alternative I, with the understanding that costs would actually be somewhat less than for Alternative I.

Capital requirements under Alternatives I or II would be lower than annual internal cash flow (depreciation and after-tax earnings) at each model plant. The ratio of annual internal funds to capital requirements under Alternatives I or II is as follows: small commercial plants, 1.64; medium commercial plants, 3.83; large commercial plants, 5.86; small industrial plants, 2.31; and large industrial plants, 1.61. These ratios are shown in Tables 9-24 through 9-28. With internal sources adequate to cover investment requirements, external financing by banks is an option but is not necessary to comply with either alternative.

Alternative III is distinctly different from the baseline in that it requires dry cleaners to adopt recovery dryers at an investment cost of approximately $23,000 each. Recovery dryers entail higher owning costs because their higher purchase cost implies greater capital charges (interest plus amortization), while the higher capital charges can be offset by savings in recovered solvent (or savings of steam). The level of dry cleaning throughput is a critical element in the feasibility of recovery dryers because the increased capital costs are fixed, while operating cost savings from use of recovery dryers depend upon the amount of cleaning and solvent use.

As mentioned earlier, the capital charges are assessed under two sets of capital recovery factors. The first factor is 10.6 percent of investment requirements and reflects a real interest rate of 10 percent amortized over 30 years. The second factor is 26.4 percent of investment requirements and reflects a real interest rate also of 10 percent, but an amortization period of five years. Industry and bank sources indicated that dry cleaners would have to repay loans in five years or less (Bray, 1982; McCracken, 1982; Shaw, 1982), even though equipment may have a longer useful life. While it is possible for firms to use a different amortization period for economic accounting purposes than their loan repayment period, the shorter repayment schedule is used as the basis for establishing an upper bound on the capital recovery factor. The capital recovery factor of 26.4 percent probably overstates annualized capital charges for most dry cleaners but provides a conservative basis for determining impacts.

With a five year amortization period, Alternative III would cause annualized costs to decrease at three of the five model plants. The decreases in annualized costs would be: large commercial plants, $3,600; small industrial plants, $6,600; and large industrial plants, $34,100 (see Table 9-21). If a 30 year amortization period were assumed, cost reductions would be much greater, as shown in Tables 9-24 through 9-28. Cost reductions, rather than increases, indicate that plant finances would actually be improved, rather than weakened, by Regulatory Alternative III. The reason for this is that solvent prices have increased greatly from the past and large plants in the industry are now better off recovering solvent to the extent possible.

At the other extreme, the small commercial model plant would not attain sufficient solvent recovery credits to offset the higher capital charges of owning recovery dryers. With a five year amortization period, net annualized costs would increase by $4,400 or approximately 90 percent of baseline earnings before taxes. Plants unable to pass through the increased costs could have their earnings substantially eliminated. Assuming an amortization period of 30 years would lessen the level of cost increase to $1,400 but would still jeopardize 30 percent of baseline earnings. The extent of these cost increases at a small commercial model plant indicates that small plants would be adversely affected by Alternative III unless exempted.

The medium commercial model plant has a mixed set of results. With a five year period for amortization of investments, net annualized costs would increase by $2,700 (23 percent of baseline earnings before taxes). With a 30 year amortization period, net costs would decrease by $300 (two percent of baseline earnings). Because many dry cleaners would amortize their equipment in approximately five years, costs, in many cases, would increase by approximately $2,700 and would jeopardize a sizable fraction of the earnings at medium commercial plants. Medium commercial plants would also benefit if an exemption were allowed, although they would not be as severely affected if not exempted as would small commercial plants. To the extent the high capital recovery factor of 26.4 percent overstates such charges, though, the degree of cost increases would be less.

The feasibility of financing the capital requirements at plants under Alternative III is indicated by two ratios shown in Tables 9-24 through 9-28. As a first test of financial feasibility, annual internal cash flow is compared with Alternative III capital requirements. Unlike the case with Alternatives I or II, where internal cash flow exceeds capital requirements at all five model plants, only one model plant has annual internal cash flow greater than capital requirements for Alternative III. The large commercial plant has a ratio of 1.61 for internal cash flow in relation to capital requirements. The ratios at the other model plants are: small commercial plants, 0.28; medium commercial plants, 0.65; small industrial plants, 0.67; and large industrial plants, 0.78.

Financing from banks probably would be needed. The availability of debt financing from banks depends primarily on two factors. The first factor is the extent to which a loan would repay itself. As found above, all plants except small and medium commercial plants would be able to repay capital charges without any decreases in earnings. Medium commercial plants would have a substantial cushion of earnings from existing operations to cover repayment of a loan, but small commercial plants would be in a tenuous situation.

The ability of firms to absorb capital charges in their financial structure is reflected by the interest coverage ratio described earlier. This ratio relates overall earnings to interest payments. Average commercial dry cleaners have a ratio of 3.3 times interest and industrial plants a ratio of 3.6 times interest (Robert Morris Associates, 1979-1981). (Due to data limitations, the industrial sector average reflects the ratio for the linen supply industry, which is related to the industrial cleaning industry.)

Assuming that dry cleaners financed equipment entirely from debt with a 10 percent real interest rate and five year amortization period, the interest coverage ratios for Alternative III would be as follows: small commercial plants, 1.1 times interest; medium commercial plants, 1.9; large commercial plants, 2.9; small industrial plants, 2.6; and large industrial plants, 3.2. Ratios assuming an amortization period of 30 years would be higher, as shown in Tables 9-24 through 9-28.

Generally, interest coverage ratios should remain at a level at least twice interest payment obligations to allow for occasional decreases in earnings or other adverse contingencies. Hence, while ratios would be adequate at the large commercial, small industrial, and large industrial plants, the ratios would not be strong at the small or medium commercial plants. Small commercial plants would have almost no margin for contingencies and would therefore not be able to find banks willing to finance equipment purchases of this magnitude. Medium commercial plants, with a ratio of 1.9, are close to the necessary margin but may have problems in instances where particular dry cleaners have baseline ratios below the industry average of 3.3.

However, the decline in interest coverage ratios may be overstated here because 100 percent debt financing has been assumed, even though banks require dry cleaners to contribute at least 10 or 20 percent of capital requirements from their own resources (Bray, 1982; McCracken, 1982; Moore, 1982). In addition, the 26.4 percent capital recovery (based upon real interest rates) is generally higher than many firms would face and therefore overstates interest payments. Nonetheless, the 1.9 ratio for medium commercial plants indicates that some plants with marginal ratios in the baseline might have difficulties financing outlays of $23,000.

Because the costs and feasibility of financing for recovery dryers relate closely to the scale of dry cleaning throughput at plants, a level of throughput can be identified at which the net annualized costs of Alternative III would be no greater than those of Alternative I. The breakeven, compared to the baseline, occurs at a throughput level of 59,940 kilograms (132,170 pounds) per year. At this level, as shown in Tables 9-29 and 9-30, there would be no increase in annualized costs. This is true for both commercial and industrial plants, since the breakeven is determined on the basis of capital charges and solvent (or steam) savings, rather than plant revenues. Derivation of the breakeven level is plotted graphically in Figure 9-1, which assumes (as do Tables 9-29 and 9-30) that baseline economics in the range shown reflect the kind of equipment used at medium commercial plants. If baseline equipment for large commercial plants were assumed, Alternative III costs at this level would actually be less than in the baseline because the $23,000 investment cost of a recovery dryer would be compared against the $6,400 capital cost for baseline large commercial plants rather than the $3,900 capital cost for baseline medium commercial plants. The breakeven level falls in the scale range between medium and large commercial plants.

A commercial plant at the breakeven throughput level would have total revenues of $272,100 and annual cash flow from operations equal to 124 percent of the capital requirements for Alternative III, as shown in Table 9-29. This indicates that plants would be in a strong position to fund capital requirements largely from internal sources. In the event a commercial plant of this size financed the capital requirements entirely from debt, though, the interest coverage ratio would remain strong at 2.3,

Table 9-29. FINANCIAL FEASIBILITY INDICATORS FOR A BREAKEVEN LEVEL[a] COMMERCIAL PLANT: ANNUAL DRY CLEANING THROUGHPUT OF 59,940 KILOGRAMS (132,170 POUNDS)

(thousands of first quarter 1981 dollars)

Regulatory alternative	Capital requirements	Increase (decrease) in earnings before taxes[b]		Annual cash flow as a percent of capital requirements[c]	Interest coverage ratio if all-debt financed[d]
		Amount	As a percent of baseline		
Assuming a 30-year amortization period[e]					
Alternative I[f]	3.9	-	-	722	3.3
Alternative III[g]	22.5	2.9	14	124	3.2
Assuming a 5-year amortization period[e]					
Alternative I[f]	3.9	-	-	722	3.3
Alternative III[g]	22.5	0.0	0	124	2.5

[a] The breakeven level represents the throughput at which net annualized costs for Alternative III are the same as the baseline assuming a 10 percent real interest rate and five year amortization period.

[b] The difference in net annualized cost from the baseline.

[c] Annual cash flow is depreciation plus after-tax earnings from existing operations.

[d] Interest coverage is the ratio of earnings before interest and taxes divided by interest payments. The baseline is assumed to equal the industry average ratio. Industry average ratios are 3.3 among commercial dry cleaners and 3.6 among industrial plants (Robert Morris Associates, 1979-1981).

[e] Assumes a real interest rate of 10 percent.

[f] Alternative I is the baseline. It consists of the replacement of petroleum dryers with equipment of the same conventional type.

[g] Alternative III involves both good housekeeping practices and adoption of recovery dryers. Recovery credits for solvent saved are the midpoints of the ranges presented in Chapter 8.

Table 9-30. FINANCIAL FEASIBILITY INDICATORS FOR A BREAKEVEN LEVEL[a] INDUSTRIAL PLANT: ANNUAL DRY CLEANING THROUGHPUT OF 59,940 KILOGRAMS (132,170 POUNDS) (thousands of first quarter 1981 dollars)

Regulatory alternative	Capital requirements	Increase (decrease) in earnings before taxes[b] Amount	Increase (decrease) in earnings before taxes[b] As a percent of baseline	Annual cash flow as a percent of capital requirements[c]	Interest coverage ratio if all-debt financed[d]
Assuming a 30-year amortization period[e]					
Alternative I[f]	3.9	-	-	386	3.6
Alternative III[g]	22.5	2.9	23	66	3.3
Assuming a 5-year amortization period[e]					
Alternative I[f]	3.9	-	-	404	3.6
Alternative III[g]	22.5	0.0	0	66	2.3

[a] The breakeven level represents the throughput at which net annualized costs for Alternative III are the same as the baseline assuming a 10 percent real interest rate and five year amortization period. An industrial plant with this throughput level would use the same equipment as a commercial plant, not the equipment of a small industrial model plant. The plant is assumed to have a 50-50 mix of dry cleaning and laundry.

[b] The difference in net annualized cost from the baseline.

[c] Annual cash flow is depreciation plus after-tax earnings from existing operations.

[d] Interest coverage is the ratio of earnings before interest and taxes divided by interest payments. The baseline is assumed to equal the industry average ratio. Industry average ratios are 3.3 among commercial dry cleaners and 3.6 among industrial plants (Robert Morris Associates, 1979-1981).

[e] Assumes a real interest rate of 10 percent.

[f] Alternative I is the baseline. It consists of the replacement of petroleum dryers with equipment of the same conventional type.

[g] Alternative III involves both good housekeeping practices and adoption of recovery dryers. Recovery credits for solvent saved are the midpoints of the ranges presented in Chapter 8.

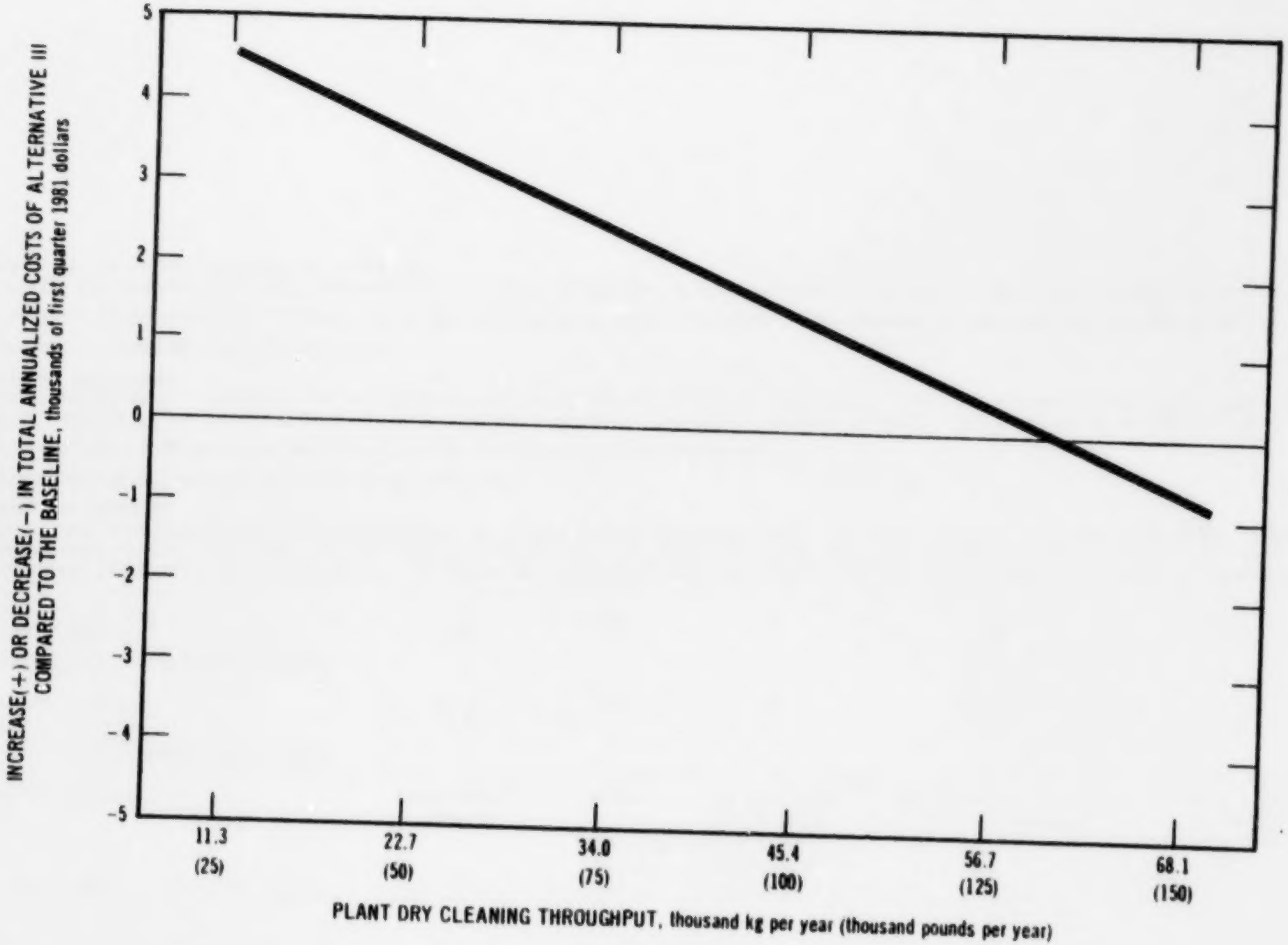

Figure 9-1. Relationship of net annualized costs for Alternative III to plant throughput assuming an amortization period of five years.

assuming a five year period for amortization, or 3.3, assuming a 30 year period.

An industrial plant having the breakeven throughput level of dry cleaning (and an equal throughput level of laundry) is shown in Table 9-30. A breakeven industrial plant would have total revenues of $224,700 and annual cash flow equal to 66 percent of capital requirements for Alternative III. (Cash flow from dry cleaning operations alone would amount to 33 percent of capital requirements for Alternative III.) The interest coverage ratio, if capital requirements were financed entirely from debt, would be 2.3, assuming a five year amortization period, or 3.3, assuming a 30 year period.

An exemption level set at, or near, the breakeven level would allow small and medium commercial plants to forego use of recovery dryers if they were uneconomic or too expensive to finance. Plants at, or above, the breakeven level would not be adversely affected by Alternative III and, in many instances, would have increases in earnings from adoption of recovery dryers.

The breakeven level is an approximate point. Plants with throughput levels near the breakeven would have essentially the same financial conditions as would plants at the breakeven. For example, a plant with an annual throughput level 2,270 kilograms (5,000 pounds) lower than the breakeven identified above would have a cost increase of $210 compared to the baseline. This would be less than one percent of commercial plant baseline earnings of $22,770. Hence, Alternative III standards with an exemption set within several thousand kilograms of the 59,940 kilogram level also would have negligible impacts on plant earnings and finances and would essentially be at the breakeven level.

In addition to the economic conditions described earlier, two factors help strengthen dry cleaners' ability to comply with standards. First, equipment life can be prolonged. Industry representatives indicate there are machines operating today that were built more than 30 years ago (Oakes, 1980; Nieckula, 1981; Woolsey, 1981). This durability allows firms leeway to continue operations until finances improve. A reserve for replacements can be set aside to build up funds, and replacements postponed until the reserve has been accumulated to an adequate level.

Also, financing is available on a last-resort basis from the U.S. Small Business Administration (SBA). The SBA offers direct loans, participation in bank loans, and guarantees of bank loans where firms meet certain SBA criteria. Decisions by the SBA always are made on a case-by-case basis, but these major economic criteria can be identified (SBA, 1978; SBA, 1980a; U.S. Senate, 1980a):

- Financing from private commercial sources must not be available on reasonable terms.
- Repayment must be reasonably assured and the business must show an ability to operate successfully.
- The business must have enough capital to be able to operate on a sound financial basis with the SBA loan.
- Collateral must be available to secure term loans.

The essence of the SBA loan criteria is that SBA would make loans available when applicants with reasonably successful prospects have not been able to obtain commercial financing. The SBA might be less restrictive than commercial banks in assessing risks. One banker, asked about the feasibility of relying on SBA loans as a safety net for financing dry cleaning standards, indicated that, while a number of dry cleaners use SBA loan programs, it is unclear whether dry cleaners systematically could obtain such financing (Merrill, 1981).

Petroleum dry cleaners replacing equipment would be above-average among small businesses in creditworthiness in the general sense that replacements of dryers are not made until 20 to 30, or more, years of operations have elapsed. Hence, petroleum dry cleaners seeking loans would be well-established firms with long service records.

9.2.5 Employment

Employment in the dry cleaning industry would not be affected adversely by emission standards for petroleum dry cleaning. Labor use at plants is the same for all of the regulatory alternatives, except in the case of large industrial plants. Large industrial plants would use slightly more labor under Alternative III standards than they would in the baseline.

Because plant closings are unlikely (with the possible exception of some small plants under Alternative III if no exemption were allowed), the effects of emission standards on employment would be limited. As shown in Table 9-3, more than half of all commercial dry cleaners (and virtually all small dry cleaners) have fewer than five employees. Any plant closures would affect few workers. There would not be any large plant closings of a scale that would depress local communities.

Moreover, aggregate dry cleaning industry employment will not decrease under any regulatory alternative. Because prices for dry cleaning services are not expected to increase, aggregate demand for dry cleaning services will be unaffected, implying that the derived demand overall for employment should remain unchanged.

9.2.6 Small Business Aspects -- Regulatory Flexibility Act

To a large extent, small business aspects of the standards have been considered in the model plant analyses. An examination was made of plants of various sizes, including small commercial plants with 14,000 Kg (30,000 pounds) of annual dry cleaning throughput. Moreover, because this industry is a diverse, fragmented industry, particular caution has been taken in interpreting the results of the financial tests in the case of the smaller plants. The Small Business Administration has several definitions for small businesses. In the case of service industries, "small" is defined as having revenues less than or equal to $2 million (SBA, 1980b). Almost all petroleum dry cleaners qualify as small businesses under this definition, except for large industrial plants.

Few small dry cleaners would be adversely affected by the standards, particularly if small plants were exempted. As stated in Section 9.1.8, dry cleaners would incur costs exceeding the baseline only when they have affected dryers (under Alternative III). Hence, while the projections for total affected facilities indicate there would be 5,125 affected facilities (items of equipment) in the commercial sector and 695 affected facilities in the industrial sector, only 1,025 commercial dry cleaning plants and 55 industrial dry cleaning plants would have affected dryers and incur investment costs above the baseline. Accordingly, while in theory the affected facility totals imply that 78 percent of the 6,150 commercial petroleum dry cleaners and all of the 230 industrial petroleum dry cleaners could have at least one affected facility (item of equipment), investment costs above the baseline would be incurred only at the 16.7 percent of all commercial petroleum dry cleaners and 23.9 percent of all industrial petroleum dry cleaners with affected dryers.

Further, recovery dryers would produce net cost savings at large commercial, small industrial, and large industrial plants (or only moderate cost increases at most medium commercial plants), and were shown to be financially affordable. Adversely affected dry cleaners would include only the 100 small commercial dry cleaners with affected dryers and a portion of the 690 medium commercial dry cleaners with affected dryers; however, an exemption level based on cleaning throughput related to the approximate breakeven level for recovery dryers would exempt virtually all such firms. In sum, small dry cleaners would not have significant adverse impacts from the standards.

9.2.7 Equipment Manufacturers

Dryers are the major pieces of equipment whose sales will be affected by the requirements of the NSPS. Manufacturers of conventional petroleum solvent dryers report that baseline sales of conventional petroleum dryers are down compared to a decade ago (Rosenthal, 1981a). For other than recovery dryers, the sales outlook is limited and firms are operating largely on the strength of their perchloroethylene, laundry, or other equipment sales. Rising solvent prices and the preference for perchloroethylene units among new dry cleaners have limited petroleum dryer sales (Rosenthal, 1981a; Oakes, 1980).

Petroleum dry cleaning emission standards at the Alternative III level would make recovery dryers mandatory for affected facilities. At present, recovery dryers are sold in the U.S. by only a single firm, raising the issue of potential production bottlenecks or monopoly supplier conditions.

The issue of production bottlenecks is related partly to the number of suppliers but includes other factors. Licensing the technology for petroleum recovery dryers would make available additional suppliers of the equipment, augmenting both competitiveness and production capabilities. Section 308 of the Clean Air Act allows EPA to require holders of critical patents to license such patents on reasonable terms.

The existing U.S. manufacturer of recovery dryers is said to use primarily manual methods of equipment fabrication (Corey, 1981). Such specialty-type means of production are common in the dry cleaning manufacturing industry. Production could be expanded by increasing the amount of equipment and the number of people employed or by increasing the number of plants used to produce the equipment. In November 1981, the manufacturer of recovery dryers indicated it was expanding its manufacturing and storage area, and that sales of recovery dryers would not exceed their capacity (Manzone, 1981).

There are six manufacturers of recovery dryers in Japan; however, their recovery dryers generally are smaller than U.S. units. The cost of the Japanese dryers appears to be about the same as the U.S.-manufactured dryers (Jernigan, 1980-1981). There is no reason to expect that Japanese suppliers would influence the market to the detriment of the U.S. supplier.

9.2.8 Solvent Producers

Most petroleum solvent producers are large oil refining or chemicals companies that have substantial financial resources and manufacturing diversity. For example, Getty and Amoco had revenues in 1980 of $10.2 billion and $26.1 billion, respectively (Fortune, 1981). For such companies, the petroleum solvent market is a minor outlet for their products. A few of the petroleum solvent producers are considerably smaller. However, it is unlikely that any producer relies exclusively upon petroleum solvent sales.

Petroleum solvent is produced as a co-product with other petroleum fractions during the refining of crude oil. Unlike the synthetic solvents, such as perchloroethylene or fluorocarbon, which undergo a halogenation step, petroleum solvent is a blend of distillates (with trace additives). In the event demand for petroleum solvent declined, refiners would simply produce lower proportions of petroleum solvent from each barrel of crude oil processed; another product, such as gasoline, would be produced in greater proportion from the oil feedstock. Therefore, a decline in the demand for petroleum solvent would not cause a reduction in revenues for petroleum solvent producers. Moreover, since emissions controls would be phased in gradually, any transition in product mix would be gradual.

9.2.9 Economic Advantages of Standards

Despite the fact that recovery dryers and better work practices offer cost savings that would make them commercially attractive, standards would insure that greater numbers of dry cleaners adopted such controls. There are several reasons why many dry cleaners may resist making purchases of recovery dryers.

First, dry cleaners typically are run as small, independent operations, often by sole proprietors or families. There sometimes is resistance among dry cleaners to technological change. The greatest, and most visible, costs for dry cleaners are labor costs, not equipment costs (International Fabricare Institute, 1980b). Not all dry cleaners optimize their technology choices. Dry cleaning trade association officials have noted that association members do not always implement the technical advice given by trade associations (Sluizer, 1982), for example.

Second, information on the value, reliability, and safety of recovery dryers may not be fully distributed. Many dry cleaners may wait for extensive field testing and experience.

Third, some dry cleaners may make equipment purchases on the basis of initial investment costs (favoring lower-priced conventional dryers) rather than life-cycle costing (which would favor recovery dryers). Fourth, fluctuations and uncertainty involving petroleum solvent prices could lead to periods when some dry cleaners may undervalue future solvent savings with recovery dryers.

Standards that exempted small dry cleaners would avoid requiring petroleum recovery dryers at dry cleaners that could not afford them, yet would promote the use of this technology at most new sources in the industry. Since dry cleaning equipment is long-lived, investment patterns favoring either conventional or recovery dryers would have long-lived consequences for costs, emissions, and energy conservation.

9.3 POTENTIAL SOCIOECONOMIC AND INFLATIONARY IMPACTS

As shown in Section 9.1, the commercial petroleum dry cleaning industry is concentrated to a large extent in the South. The impacts of the standards will be reflected to a greater extent in that region.

Table 9-31 shows annualized costs and capital requirements that could result from NSPS for petroleum dry cleaning. A savings in net annualized costs, compared to the baseline, would take place for Alternative III. Industry costs in the fifth year after proposal would decrease by $3.7 million under Alternative III. The decrease in costs would be the result of savings due to petroleum solvent that is reclaimed after use and, to a lesser extent, some steam savings at industrial plants. It should be noted that these costs are based on the assumption that the real rate of interest

Table 9-31. ANNUALIZED COSTS AND CUMULATIVE CAPITAL REQUIREMENTS OF ALTERNATIVE III COMPARED TO THE BASELINE, FIFTH YEAR AFTER PROPOSAL OF NSPS[a] (thousands of first quarter 1981 dollars)

Plants	Cumulative capital requirements through fifth year	Annualized cost increases (decreases) in fifth year
Small commercial	1,866	144
Medium commercial	12,875	(186)
Large commercial	4,009	(1,469)
Small industrial	709	(211)
Large industrial	3,662	(1,940)
All plants	23,121	(3,662)

[a] Assumes solvent recovery at plants falls at the midpoint of the possible range. Costs are based on a 10 percent real interest rate and 30 year amortization. Refrigerated chillers are assumed for plants under Alternative III. Costs and capital requirements shown here refer to the excess or deficit in relation to the baseline (Alternative I).

is 10 percent, the amortization period is 30 years, and solvent recovery falls at the midpoint among possible values. Capital requirements above the baseline during the first five years of proposal would total $23.1 million under Alternative III.

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APPENDIX A. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

EPA presented a draft standard to the National Air Pollution Control Techniques Advisory Committee (NAPCTAC) in August 1976. Comments received there resulted in the separation of the different dry cleaning solvents for further study. EPA published a preliminary draft Control Techniques Guideline (CTG) Document in February 1981, and the CTG was presented to the NAPCTAC committee in March 1981. The CTG is a guide to the States for controlling petroleum solvent emissions from existing petroleum dry cleaners in non-attainment areas. In October 1979, EPA began working on the development of an NSPS for petroleum dry cleaners. A draft standard was presented to NAPCTAC in December 1981.

A.1 CHRONOLOGY

The chronology which follows includes those events which have occurred in developing the BID for petroleum dry cleaning. Anticipated events which lead up to the proposal of the standard in the Federal Register are also included.

Date	Activity
December 19, 1974	Trip concerning degreasing and dry cleaning at Dow Chemical and Vic Manufacturing.
January 28, 1975	Meeting with Neighborhood Cleaners Association.
July 28, 1975	Trip to Sterling Laundry to discuss operation.
September 4, 1975	Meeting with International Fabricare Institute to discuss control techniques and test methods of dry cleaner operations.
December 12, 1975	Meeting with Washex Machinery Corporation.

Date	Activity
December 12, 1975	Visit to an Industrial Towel and Uniform facility to observe a petroleum industrial dry cleaning operation.
August 10, 1976	National Air Pollution Control Techniques Advisory Committee (NAPCTAC) meeting on dry cleaning, Chicago, Illinois.
January 3, 1977	Trip to Interdyne Corporation to observe installation of a carbon adsorber on a petroleum dry cleaning dryer.
January 3, 1977	Meeting with Hoyt Manufacturing Representatives.
January 21, 1977	Meeting with Dry Cleaning Industry Representatives.
March 8, 1977	Meeting with Industry Representatives (Puritan Corporation).
March 16, 1977	Meeting with International Fabricare Institute Representatives.
March 29, 1977	Meeting with Representatives of the Industrial Sector of the Dry Cleaning Industry.
May 19, 1977	Meeting with Industry Representatives to present review of the dry cleaning guidelines document.
June 6, 1977	Tests conducted on a petroleum dry cleaner (Clean Glove) to establish the performance of a carbon adsorber.
July 8, 1977	Policy recommendations on regulation of VOC compounds published in the Federal Register.
August 25, 1977	Trip to Norton Cleaners to observe the performance of a centrifugal separator in service at a petroleum dry cleaner.
November 28, 1977	Meeting with W. Fisher, International Fabricare Institute to discuss carbon adsorption development for petroleum dry cleaners.

Date	Activity
February 14, 1978	Meeting regarding dry cleaning demonstration project with W. Fisher, International Fabricare Institute.
July 24, 1978	Commencement of testing of a carbon adsorption system as applied to a petroleum solvent dryer at Valley Industrial Services, Anaheim, California.
August 31, 1978	EPA proposed a list (including petroleum dry cleaners) of stationary sources for which NSPS would be written.
May 9, 1979	Petroleum Adsorber meeting with Industry Representatives.
August 21, 1979	EPA promulgated the list of stationary sources for which NSPS would be written in the Federal Register (44 FR 49222).
October 1, 1979	Work begins on Petroleum Dry Cleaning NSPS project.
October 9, 1979	Commencement of testing of Hoyt recovery dryer at M. L. Winters Cleaners, Pico Rivera, California.
October 30, 1979	Trip to Valley Industrial Services.
October 30, 1979	Trip to M. L. Winters, Pico Rivera, California.
January 29, 1980	Trip to International Fabricare Institute (IFI), Silver Spring, Maryland.
January 29, 1980	Trip to Banner-Hamilton Dry Cleaners, Hyattsville, Maryland for plant visit.
February 20, 1980	Trip to Van Dyne Crotty, Dayton, Ohio for pre-test survey.
February 26, 1980	Commencement of vacuum still waste testing at Leasetex Systems, Branford, Connecticut.
February 28, 1980	Trip to Farthing Fabric Care, Inc., Durham, North Carolina.

Date	Activity
March 5, 1980	Trip to Kwik-N-Neat, San Antonio, Texas.
March 11, 1980	Trip to Hoekstra Uniform Rental Service, South Holland, Illinois.
March 12, 1980	Trip to Cadet Cleaners, Toronto, Ontario.
March 17, 1980	Trip to Polly Prim Cleaners, Lakeland, Florida.
March 18, 1980	Trip to Challenge-Cook Bros., Inc., Industry, California.
March 18, 1980	Trip to M. L. Winters Cleaners, Pico Rivera, California for plant visit.
August 21, 1980	Commenced testing of Hoyt recovery dryer at Polly Prim Cleaners, Lakeland, Florida.
September 17, 1980	Commenced testing of solvent drainage from disposed cartridge filter elements at Williams Cleaners, Wilmington, North Carolina.
November 25, 1980	Proposal of the Perc Dry Cleaning regulation in the Federal Register (45 FR 78174).
December 8, 1980	Commenced testing of a Hoyt recovery dryer at Security Cleaners, West Warwick, Rhode Island.
December 10, 1980	Meeting with IFI, IIL, Patton Boggs and Blow, EPA, and TRW concerning industry views on CTG model regulation.
February 9, 1981	Preliminary Draft of Petroleum Dry Cleaning CTG mailed to industry, NAPCTAC, environmental groups and control agencies for their review.
February 12, 1981	Notice announcing availability of Preliminary Draft Petroleum Dry Cleaning CTG package for public comment and NAPCTAC meeting in Federal Register (46 FR 12106).
March 17, 1981	NAPCTAC meeting on Petroleum Dry Cleaning CTG, Raleigh, North Carolina.

Date	Activity
March 19, 1981	Trip to Clean '81 trade show at the Georgia World Congress Center, Atlanta, Georgia.
November 5, 1981	Notice announcing availability of preliminary draft of NSPS for public comment and NAPCTAC meeting on Petroleum Dry Cleaning NSPS in *Federal Register* (46 FR 55000).
December 1981	NAPCTAC meeting on Petroleum Dry Cleaning NSPS preliminary draft package.
November 1982	Anticipated proposal of regulation in the *Federal Register*.

APPENDIX B. INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

This appendix consists of a reference system which is cross indexed with the October 21, 1974, Federal Register (39 FR 37419) containing EPA guidelines for the preparation of Environmental Impact Statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

Table B-1. INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements 39 FR 37419	Location within the Background Information Document
(1) Background and Summary of Regulatory Alternatives	The regulatory alternatives are summarized in Chapter 1, Section 1.1.
Statutory Basis for Proposing Standards	The statutory basis for the regulatory alternatives is summarized in Chapter 2.
Relationship to other Regulatory Agency Actions	The various relationships between the regulatory alternatives and other regulatory agency actions are summarized in Chapters 3, 7, and 8.
Industry Affected by the Regulatory Alternatives	A discussion of the industry affected by the regulatory alternatives is presented in Chapter 3, Section 3.1. Further details covering the "business/economic" nature of the industry is presented in Chapters 8 and 9.
Specific Processes Affected by the Regulatory Alternatives	The specific processes and facilities affected by the regulatory alternatives are summarized in Chapter 1, Section 1.1. A detailed technical discussion of the sources and processes affected by the proposed standards is presented in Chapter 3, Section 3.2.
Availability of Control Technology	Information on the availability of control technology is given in Chapter 4.
Existing Regulations	A discussion of existing regulations on the industry to be affected by the regulatory alternatives are included in Chapter 3 and Chapter 7.

Table B-1. Concluded

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements 39 FR 37419	Location within the Background Information Document
(2) Alternative to the Regulatory Alternatives	
Environmental Impacts	Environmental effects of not implementing the regulatory alternatives are discussed in Chapters 3 and 7.
Costs	The costs of alternative control techniques are discussed in Chapters 8 and 9.
(3) Environmental Impact of the Regulatory Alternatives	
Air Pollution	The air pollution impact of the regulatory alternatives is discussed in Chapter 7, Section 1.
Water Pollution	The water pollution impact of the regulatory alternatives is discussed in Chapter 7, Section 2.
Solid Waste Disposal	The solid waste disposal impact of the regulatory alternatives is discussed in Chapter 7, Section 3.
Energy	The energy impact of the regulatory alternatives is considered in Chapter 7, Section 4.
(4) Economic Impact of the Regulatory Alternatives	The economic impact of the regulatory alternatives on costs is discussed in Chapters 8 and 9.

APPENDIX C
EMISSION SOURCE TEST DATA

This appendix provides detailed descriptions (in summary form) of EPA tests conducted in support of the petroleum dry cleaning new source performance standard (NSPS) and control techniques guideline (CTG) development. For additional and complete information on each test, refer to the referenced test reports in each section.

C.1 PLANT A (RECOVERY DRYER AND STANDARD DRYER)

EPA contracted an engineering analysis of a solvent recovery dryer and a standard dryer in an industrial petroleum dry cleaning plant to determine the emission reduction potential of the recovery dryer and establish the capital and operating costs associated with the use of both standard and recovery dryers (Jernigan and Lutz, 1980). Testing was conducted at the plant from October 9 to November 21, 1979. This dry cleaning facility utilized both a Cissell standard dryer and a Hoyt "Petro-miser" solvent recovery dryer to process approximately 6,350 kg (14,000 lbs) of industrial work gloves per week. The standard dryer had a dry weight load capacity of 45 kg (100 lbs), and the recovery dryer had a dry weight load capacity of 48 kg (105 lbs). To reflect normal operating conditions, each dryer was loaded an average of 10 percent over its rated capacity with work gloves made of cotton and leather. The recovery dryer had three operating sequences - a Reclaim-Dry Cycle, a Perma-Cool Cycle, and a Deodorizing (exhaust) Cycle. Solvent emissions from the recovery dryer were not restricted solely to the exhaust cycle. Any time the dryer loading door was open, an exhaust fan was activated and ambient room air was pulled into the dryer and exhausted to the atmosphere via the exhaust duct. This also occurred when the door to the lint filter compartment was open. In comparison, the standard dryer continuously exhausted to the atmosphere during the drying cycle.

The solvent recovery dryer's emission reduction performance was established by comparing its measured emission rate with the emission rate of a standard dryer. During the testing period, both dryers were operated simultaneously and processed similar loads. The average flow rate through the exhaust ducts during the recovery and standard dryer drying cycles was determined using EPA Method 2. The exhaust gas flow rate for the recovery dryer ranged from 285 to 308 dry standard cubic feet per minute (dscfm), with an overall test average of 290 dscfm. The exhaust flow rate for the standard dryer ranged from 1,539 to 1,735 dscfm, with an average of 1,659 dscfm over the entire test. The average solvent concentration in the recovery and standard dryer exhausts was determined during each exhaust cycle by analyzing the strip chart recordings from a Beckman 400 flame ionization analyzer (FIA). The average concentration for each dryer, multiplied by the total gas volume throughput for each dryer, yielded the total solvent emitted for each dryer in kilograms per cycle. Dividing this value by the weight of gloves dried for each dryer cycle yielded the solvent emissions for the recovery and standard dryers expressed in kilograms of solvent per 100 kilograms of gloves dried.

The average emission rates for the recovery and standard dryers were determined and expressed in kilograms of solvent per 100 kilograms of articles cleaned. Table C-1 indicates that the recovery dryer had an average emission rate per drying cycle of 0.96 kg solvent per 100 kg dry weight of articles cleaned, and the standard dryer had an average emission rate per drying cycle of 30 kg solvent per 100 kg dry weight of articles cleaned. Recovery dryer solvent emissions per 100 kilograms of articles cleaned ranged from 0.68 to 1.25 kilograms, and appeared to vary with the load weight. The total weight of solvent recovered ranged from 8 to 17 kilograms (18 to 37 pounds) and did not appear to be a direct function of the load weight. In contrast, standard dryer solvent emissions per 100 kilograms of articles cleaned ranged from 20.8 to 47.2 kilograms, and appeared to increase with smaller load weights. The trend toward higher emissions per weight of articles cleaned in smaller loads held true for both standard and recovery dryers, and indicated that the rate at which fabrics release solvent could have a significant effect on overall solvent emissions.

Table C-1. DRYER EMISSIONS DATA[a], PLANT A

Date	Load #	Load dry weight (kg)	Solvent emitted (kg)	kg solvent emitted/100 kg articles cleaned	Solvent recovered (kg)	kg solvent recovered/100 kg articles cleaned
10/09/79	2	51.9	0.352	0.68	14.85	28.6
10/16/79	2	50.8	0.496	0.98	11.11	21.9
10/17/79	2	49.0	0.598	1.22	11.34	23.1
10/17/79	3	51.4	0.462	0.90	11.56	22.5
10/17/79	4	53.7	0.486	0.91	9.75	17.3
10/17/79	5	53.3	0.471	0.88	11.11	20.1
10/18/79	2	56.2	0.424	0.76	8.73	15.5
10/18/79	3	51.7	0.407	0.79	11.68	22.6
10/18/79	4	49.8	0.611	1.23	14.06	28.2
10/18/79	5	49.2	0.569	1.16	8.16	16.7
10/22/79	2	52.1	0.448	0.86	11.45	22.0
10/22/79	3	46.2	0.577	1.25	16.78	36.3
10/22/79	4	48.9	0.471	0.96	14.29	29.2
Average				0.96		23.4

Date	Run #	Load weight (kg)	Solvent emitted (kg)	kg solvent emitted/100 kg articles cleaned
10/10/79	4	50.79	15.80	31.1
10/11/79	1	53.52	13.99	26.1
10/11/79	2	51.93	14.56	28.0
10/11/79	3	49.43	17.80	36.0
10/11/79	5	52.38	16.57	31.6
10/12/79	1	50.57	14.88	29.4
10/12/79	2	48.98	16.57	33.8
10/12/79	3	51.02	15.65	30.7
10/12/79	4	54.88	11.40	20.8
10/12/79	5	48.66	18.72	38.5
10/15/79	3	52.38	16.11	30.8
10/15/79	4	50.93	16.41	32.2
10/15/79	5	46.49	21.94	47.2
10/16/79	2	50.79	15.80	31.1
10/16/79	3	53.29	13.21	24.8
10/17/79	1	52.38	13.56	25.9
10/17/79	2	51.02	16.88	33.1
10/17/79	3	52.15	12.68	24.3
10/17/79	4	53.65	14.00	26.1
10/19/79	1	53.51	12.12	22.7
10/19/79	4	48.89	14.64	29.9
				30.1

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[a] Data tabulated only for dryer loads in which all relevant parameters were successfully monitored.

The annualized operating cost of the recovery dryer was calculated to be $1,400, which represents a savings of $3,900 per year over the operating cost of the standard dryer. This savings was due primarily to the value of the recovered solvent, estimated at $0.24/liter ($0.92/gallon) at the time of the test.

The mass balance and hydrocarbon analysis from this test program demonstrated that recovery dryers could achieve a 97 percent reduction in solvent emissions as compared with a standard dryer. The economic analysis of this type of control system indicates that it is a cost-effective means of solvent emission control, providing an actual reduction in operating costs.

One problem that was not resolved during this test was whether the recovery dryer operated above the lower explosive limit (LEL) of the solvent (1 percent by volume or 10,000 parts per million). FIA chart recordings of the vapor concentrations in the recovery dryer during the reclaim-dry cycle indicated that the vapor concentration rose until it peaked at 9,000 to 9,300 parts per million (ppm) as solvent. The vapor concentration remained at this peak throughout most of the drying cycle. After the testing was completed, careful analysis of the chart recordings revealed that these peak readings were not the maximum concentration levels, but the level at which the FIA became saturated; thus, indicating only the maximum monitoring levels of the calibrated FIA. Therefore, the actual concentrations of the solvent vapors in this particular recovery dryer may have exceeded the peak range of 9,000 to 9,300 ppm.

The high vapor concentrations during the reclaim cycle may be attributed to a number of factors. Overloading of the dryers, as was the case during this test, may have caused the high concentrations. Fabric with high solvent absorption, such as cotton and leather, give off more solvent vapors than an equal weight of synthetic fabrics, thereby creating higher concentrations. Also, high condenser inlet water temperatures may contribute to high vapor concentrations during the reclaim cycle.

C.2 PLANT B (RECOVERY DRYER)

An EPA-sponsored testing program was performed at a commercial petroleum dry cleaning facility to investigate the solvent emissions and recovery, operating costs, and safety of a petroleum solvent recovery dryer (Jernigan et al., 1981). The host plant for this test program was a large commercial dry cleaning plant that cleaned about 1,100 kg (2,500 lbs) of general apparel each week. The dry cleaning equipment consisted of a 48 kg dry weight (105 lb) capacity Hoyt recovery dryer, a 30 kg (65 lb) capacity Washex washer/extractor, an 11,000 liter per hour (3,000 gph) Washex tube filter, and a 48,000 Btu (50 MJ) Rite Temp refrigerated water chiller. Testing was conducted at this facility from July 21 to August 8, 1980.

Test procedures included monitoring exhaust gas and condenser gas inlet solvent concentrations using a Beckman 400 flame ionization analyzer (FIA). Also, temperatures of condenser inlet and outlet (water and gas) and dryer exhaust gas were monitored during this program. Chiller outlet (condenser water inlet) temperatures were systematically increased in 3°C (5°F) increments with a constant reclaim cycle duration (28 minutes), and solvent recovery rate and concentration data were recorded for several clothing loads at each of the chiller temperatures in order to examine the relationship between the condenser water inlet temperature and the overall dryer performance. The daily average exhaust gas flow rate was determined by EPA Reference Test Method 2, and ranged from 301 to 312 dscfm, with an overall test average of 306 dscfm. The total recovery of both solvent and water, as well as the total flow of cooling water through the condenser during the reclaim cycle, were recorded and are listed on Table C-2.

The mass balance and hydrocarbon analysis results from this test program indicated that the average VOC emissions rate from the recovery dryer was 3.85 kg VOC per 100 kg dry weight of articles cleaned. The solvent concentration at the condenser gas inlet ranged from 4,410 to 9,425 parts per million (ppm), with an average of 7,170 ppm, and never exceeded 95 percent of the solvent's lower explosive limit (LEL) of 10,000 ppm during the portion of the test in which the condenser water inlet temperature was varied.

Data collected during the test is summarized in Table C-2. As condenser water inlet temperatures were increased, condenser vapor outlet temperatures increased and solvent emissions per 100 kg of articles

Table C-2. RECOVERY DRYER DATA COMPILATION, PLANT B

Start time	Date and run	Condenser inlet water temp (°F)	Average condenser vapor outlet temp (°F)	"Dry" load weight (kg)	Recovery (kg)		Solvent emitted (kg)	kg solvent emitted/100 kg articles cleaned	kg solvent recovered/ 100 kg articles cleaned
					Water	Solvent			
0829	8/4-2	64	87	31.29	0.010	3.21	1.16	3.71	10.26
0905	3	64	--	29.93	0.155	3.19	1.23	4.12	10.66
0941	4	64	89	26.30	0.350	2.59	1.26	4.78	9.85
1034	5	66	89	23.13	0.255	2.18	1.14	4.92	9.42
1113	6	65	89	17.23	0.245	1.52	1.02	5.95	8.82
1154	7	66	91	24.94	0.440	2.36	1.07	4.27	9.46
1240	8	65	89	39.00	0.599	4.18	1.27	3.24	10.72
1321	9	65	89	9.98	0.220	1.43	0.94	9.45	14.32
0719	8/5-2	63	88	19.95	0.315	2.25	1.04	5.20	11.28
0812	3	66	91	27.66	0.420	2.91	1.14	4.13	10.52
0856	4	68	92	30.39	0.499	3.19	1.22	4.00	10.50
0941	5	68	92	29.02	0.335	3.13	1.34	4.63	10.79
1020	6	68	92	34.01	0.499	3.60	1.42	4.19	10.59
1058	7	68	92	29.93	0.450	3.22	1.31	4.38	10.76
0727	8/6-1	64	87	23.13	0.165	2.06	0.72	3.12	8.90
0815	2	68	91	29.48	0.370	3.34	0.89	3.03	11.32
0857	3	70	94	29.02	0.499	3.07	0.88	3.02	10.59
0939	4	71	94	26.30	0.450	2.83	0.78	2.97	10.76
1028	5	70	93	22.68	0.360	2.25	0.73	3.22	9.92
1109	6	70	94	26.76	0.467	2.44	0.67	2.49	9.12
1152	7	72	95	24.04	0.375	2.63	0.63	2.60	10.94
1233	8	72	94	20.86	0.385	2.15	0.65	3.11	10.31
0706	8/7-1	70	94	27.66	---	--	0.71	2.56	--
0754	2	73	95	20.86	0.240	1.97	0.67	3.22	9.44
0834	3	73	96	28.12	0.370	2.93	0.79	2.79	10.42
0924	4	75	97	31.29	0.467	3.26	0.79	2.51	10.42
1009	5	74	95	---	---	--	0.57[a]	--	--
1048	6	74	95	24.04	0.370	2.74	0.56	2.34	11.40
Averages				25.10			0.96	3.85	10.44

[a] Data not used in computing averages.

cleaned decreased. Uncontrolled theoretical solvent emissions (defined as the sum of recovered and emitted solvent, excluding the quantity of solvent remaining in the articles after drying) per 100 kg of articles cleaned varied from 23.73 kg to 11.59 kg, with an overall test average of 14.24 kg per 100 kg of articles cleaned. Recovery dryer exhaust cycle emissions per 100 kg of articles cleaned, measured at the dryer exhaust by the FIA, varied from 9.45 kg to 2.34 kg, with an overall test average of 3.85 kg solvent emitted per 100 kg of articles cleaned. This relatively high emission rate may result from the typically small load weights (25 kg average) of synthetic fabrics that have a low solvent retention. Also, the typical recovery phase duration of 28 minutes may be insufficient time for a more complete recovery.

Figures C-1, C-2, and C-3 represent a typical range of recovery dryer loads and emissions. A dryer load with relatively high emissions (approximately 5.2 kg solvent emitted per 100 kg of articles cleaned) is illustrated in Figure C-1. The gradual increase in the volume of solvent is reflected in the narrow peak of the solvent recovery rate. Simultaneously, the concentration of solvent vapor in the condenser inlet climbs steadily during the first 7 minutes of recovery and then levels off at a near constant concentration of 4,400 parts per million (ppm) as solvent. The curve, representing the volume of recovered solvent, has a brief initial period of rapid recovery that is followed by a gradual increase in total volume that reflects a low, nearly constant rate of recovery.

Recovery and concentration curves in Figure C-2 illustrate a dryer load in which solvent emissions were below those of the test average (approximately 2.4 kg solvent emitted per 100 kg of articles cleaned). The graph of condenser inlet vapor concentration shows a much higher (9,358 ppm as solvent) and more pronounced peak than Figure C-1, in addition to much higher concentrations throughout the entire cycle. Concurrently, the curve illustrating the volume of recovered solvent shows an initial period of very rapid recovery that gradually decreases to a lower, near constant rate later in the drying cycle than in the high-emission load. Finally, the curve representing the solvent recovery rate shows a more gradual decrease in recovery rate than that illustrated

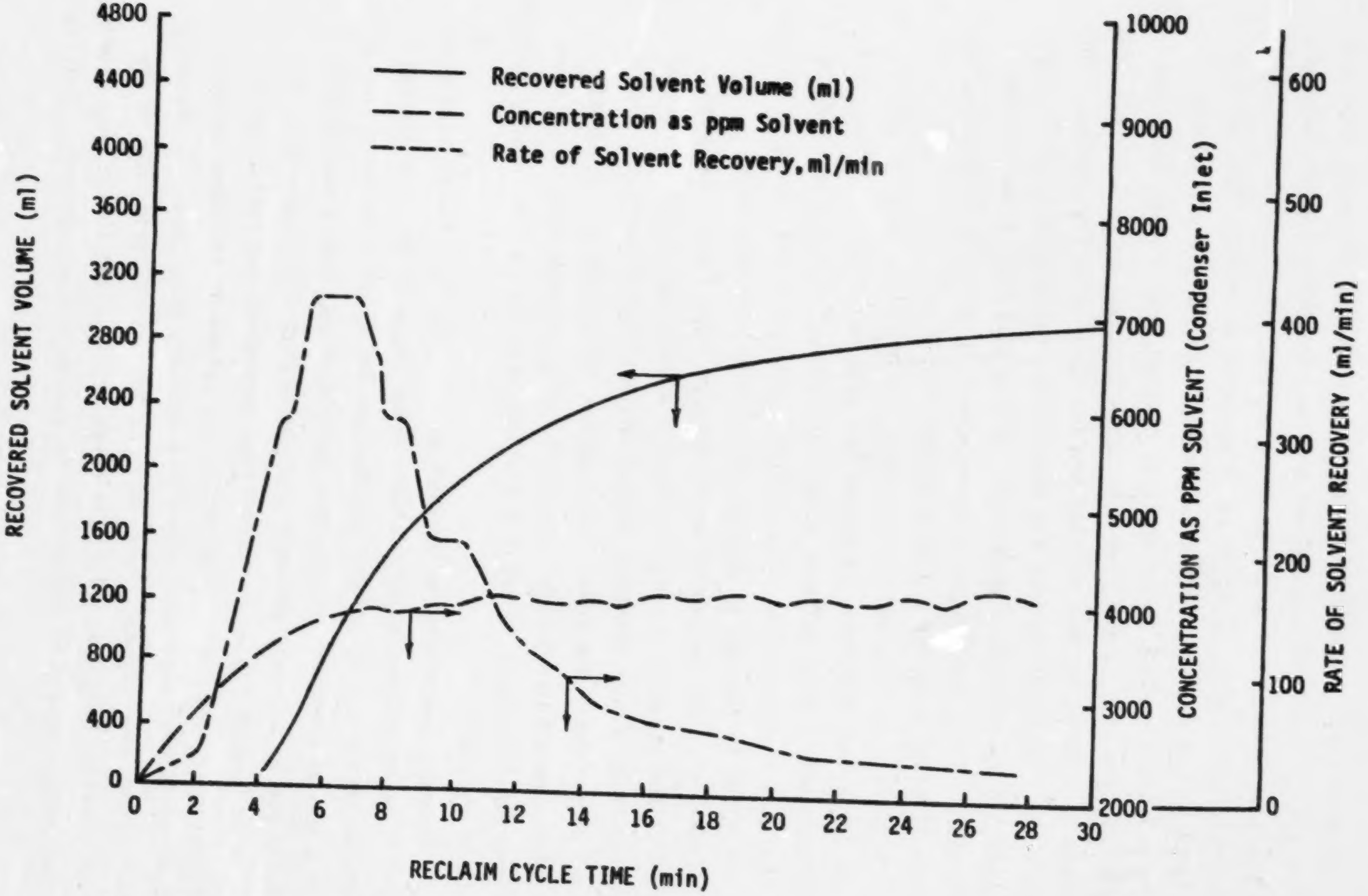

Figure C-1. Recovery and Concentration Curves for a High-Emission Recovery Dryer Load, Plant B.

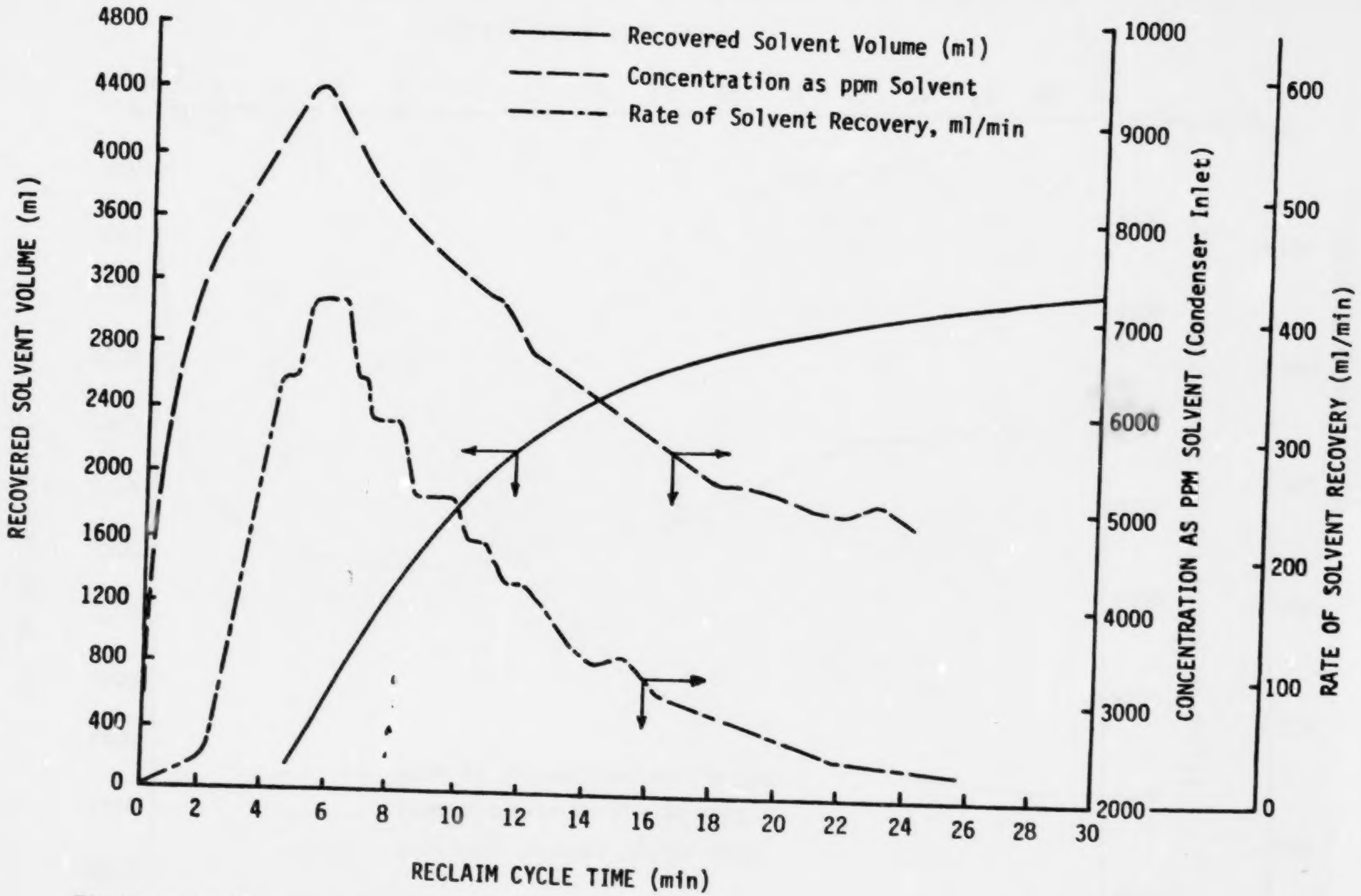

Figure C-2. Recovery and Concentration Curves for a Low-Emission Recovery Dryer Load, Plant B.

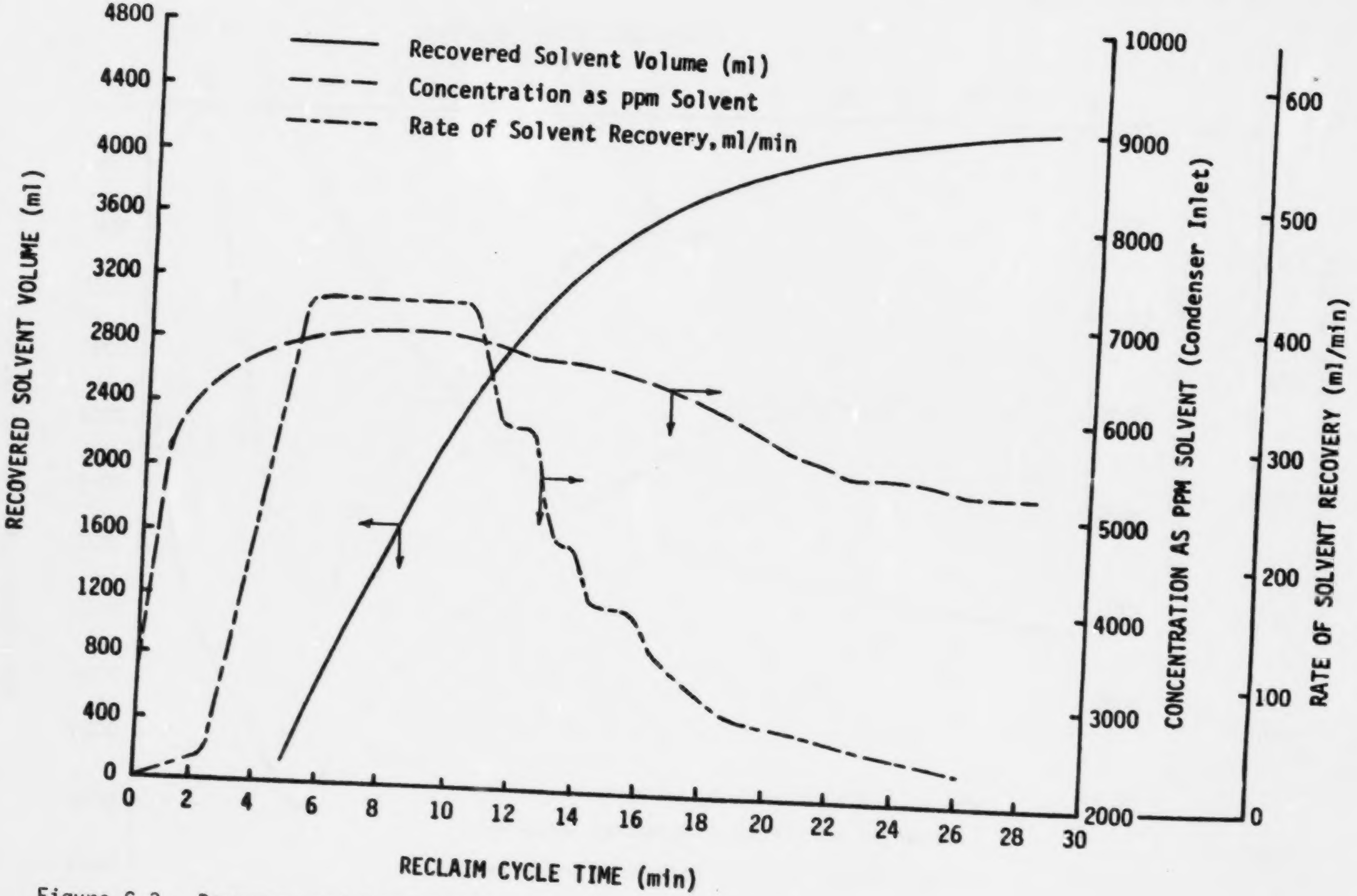

Figure C-3. Recovery and Concentration Curves for a Recovery Dryer with Test-Average Emissions, Plant B.

in Figure C-1, although the peak rate is approximately the same. At the termination of the recovery cycle, the rate of solvent recovery had decreased to a final value of 20 milliliters (0.02 liters) per minute. The average condenser gas outlet temperature for this dryer load did not exceed 34°C (94°F).

Figure C-3 illustrates a dryer load that had total solvent emissions (3.71 kg solvent per 100 kg articles cleaned) approximately equal to the overall test average of 3.85 kg solvent per 100 kg articles cleaned. The curve representing the condenser inlet vapor concentration shows somewhat more of a peak than that of Figure C-1, but a much less pronounced and lower (5,810 ppm as solvent) peak than that of Figure C-2. Simultaneously, the curve illustrating the volume of solvent recovered (Figure C-3) shows a rapid, sustained increase in total reclamation. This rate is further illustrated in the graph of the recovery rate which stays at a higher rate over the total cycle due to the heavier weight of this dryer load.

The overall decrease in exhaust cycle solvent emissions per weight of articles cleaned that accompanied the increase in condenser water inlet temperature appeared to result from the higher solvent vapor concentrations associated with higher temperatures in the dryer tumbler. The rate of solvent condensation in the condenser appeared more dependent on the rate at which solvent was evolved from the drying articles than on the temperature of the cooling water. The 6°C (10°F) actual increase in the condenser water inlet temperature did not appreciably hamper solvent condensation. Thus, emission reduction might be enhanced by increasing the temperature within the dryer; either by increasing the pressure (temperature) of the steam, or by increasing the cooling water temperature. This drying temperature increase, however, could result in solvent concentrations in the tumbler reaching the solvent LEL of 1 percent by volume (10,000 ppmv).

One of the objectives of the test was to determine a "uniform dryness," a level of solvent concentration that would indicate sufficient dryness and solvent recovery. This goal was not attained because of difficulties encountered in the test contractor's equipment and the lack of control over the weight and fabric composition of drying loads. FIA measurements of solvent concentrations were suspended for two days during the test as a result of solvent vapor condensation in the sampling system and the FIA. This problem was resolved with the acquisition of a new FIA. Also, the determination of the solvent content of the dried articles was hampered by the limited accuracy (±0.5 kg) of the plant scales used to weigh the washed and dried loads.

C.3 PLANT C (RECOVERY DRYER)

This EPA-sponsored test program was initiated with the overall objective of analyzing the performance of the petroleum solvent recovery dryer, as indicated by the maximum solvent concentration, solvent emissions, and solvent recovery, while dryer operating parameters were varied over a range that would be representative of that encountered in the industry. Furthermore, the overall reduction in plant solvent consumption (solvent mileage) was to be determined (Plaisance et al., 1981).

A Hoyt Petro-Miser 105 solvent recovery dryer was tested for two weeks (December 8-19, 1980) at a dry cleaning plant that cleans about 2,700 kg (6,000 lb) of personal apparel per week. During the test, solvent concentrations in the dryer tumbler and exhaust were measured to determine, respectively, the maximum solvent concentration during drying and the mass of solvent emitted during the exhaust cycle. Additional measurements of the volume and rate of solvent recovery were made, and load weights and relevant temperatures were recorded. Parameters relating to the dryer operation (load weight, reclaim duration, fabrics, temperatures) were varied and the effects of these variations on emissions, recovery, and concentrations were noted. Finally, data on plant solvent consumption prior to recovery dryer installation were obtained from plant management.

Analysis of the data collected indicated that the magnitude of the maximum solvent concentrations was below expected levels, based on results of previous tests. These low concentrations resulted from persistent difficulties with solvent condensation in the concentration sampling system, brought about by low ambient temperatures. While data on the absolute magnitude of dryer concentrations may have been of questionable value (the maximum value recorded was 3,537 ppmv as solvent) the relative variations in concentrations among dryer loads was found to be valid and consistent with variations in dryer operating parameters. Thus, it was found that the dry load weight and drying (condenser vapor inlet) temperature had the greatest impact on the relative level of solvent concentrations in the dryer.

An analysis of the effects of variations in dryer operating parameters on solvent recovery and emissions indicated that dry load weight and condenser heat removal had the greatest effect on dryer performance, with increases in both parameters corresponding to both higher solvent recovery and reduced solvent emissions. Over the entire test program, exhaust cycle solvent emissions averaged 3.47 kg per 100 kg dry weight of articles dried, and solvent recovery averaged 12.98 kg per 100 kg dry weight of articles dried. Plant solvent mileage consumption, as reported by plant management, decreased from about 560 liters (150 gal) per week to about 90 liters (25 gal) per week after installation of the two recovery dryers.

Table C-3 contains the data collected during the test program. Exhaust cycle solvent emissions ranged from 1.2 to 7.6 kg VOC per 100 kg dry weight of articles dried, while solvent recovery ranged from 9.9 to 17.7 kg solvent recovered per 100 kg dry weight of articles dried.

Graphs of recovery dryer performance in dryer loads with low, high, and test average emissions are plotted in Figures C-4, -5, and -6. The load (Figure C-4) with the lowest emissions per dry load weight (1.2 kg VOC/100 kg articles dried) has a pronounced "peak" in the solvent concentration after about 10 minutes of recovery that corresponds with the onset of the maximum recovery rate. At the same time, the curve representing the volume of recovered solvent shows a consistent increase in the total volume that decreases significantly only during the last 10 minutes of recovery. In contrast, the high-emission dryer load (7.6 kg VOC emitted/100 kg articles dried) represented in Figure C-5 shows a more consistent tumbler solvent concentration with a narrower peak, a lower maximum recovery rate over a shorter period, and a slowly increasing total volume of recovered solvent that reaches a plateau of approximately 3,000 ml after only 20 minutes of recovery. And finally,

Table C-3. RECOVERY DRYER DATA COMPILATION, PLANT C

Run (date - #)	Load composition	Wet load weight (kg)	Dry load weight (kg)	Reclaim cycle start time	Reclaim cycle duration (min.)	Recovered water (kg)	Recovered solvent (kg)	Kg solvent recovered/ 100 kg dry load weight	Emitted solvent (kg)	Kg solvent emitted/ 100 kg dry load weight	Maximum solvent concentration at condenser vapor inlet (ppmv solvent)	Average condenser water inlet temperature (°C)	Average condenser water outlet temperature (°C)	Average condenser water temperature difference (°C)	Average condenser water flow rate (liters/min.)	Average cooling water heat gain (kilojoules)	Average drying (condenser vapor inlet) temperature (°C)	Average condenser vapor outlet temperature (°C)
12/11-1	M	46.83	38.67	0920	--	1.17	5.54	14.33	--	--	--	15.5	28.7	13.2	--	--	58.2	26.4
2	M	37.76	29.37	1004	25	1.07	4.23	14.40	0.84	2.87	--	16.6	30.0	13.4	11.7	16384	62.2	25.3
3	M	30.73	25.63	1050	25	0.92	3.36	13.11	0.96	3.73	--	17.3	30.2	12.9	13.8	18603	63.0	24.4
4	M	40.82	34.59	1328	25	0.85	4.10	11.86	0.96	2.78	--	17.7	30.4	12.7	11.4	15130	64.2	26.0
5	M	38.67	32.89	1414	25	0.80	4.32	13.13	0.98	2.98	--	19.6	32.8	13.2	15.6	21519	53.9	26.1
12/12-1	M	45.59	37.65	0957	30	0.25	4.85	12.88	1.06	2.82	--	15.8	27.6	11.8	--	--	57.6	22.4
2	M	30.62	25.85	1043	30	0.20	3.87	14.97	0.68	2.63	--	14.3	26.1	11.8	--	--	65.0	22.7
3	M	18.94	15.88	1154	30	0.55	2.05	12.91	0.88	5.54	--	15.3	28.2	12.9	15.9	25721	71.4	23.6
4	M	38.22	31.98	1310	30	0.75	4.78	14.95	0.93	2.92	2772	15.4	27.7	12.3	17.4	26838	62.6	22.4
5	M	27.56	23.25	1353	30	0.75	2.77	11.91	0.74	3.20	2836	14.8	26.5	11.7	16.9	24795	68.3	22.5
12/15-1	S	19.62	16.33	0814	30	0.86	2.16	13.23	0.64	3.92	--	11.1	22.6	11.5	20.6	29707	67.7	18.4
2	W	22.57	18.60	0900	30	0.72	2.27	12.20	0.55	2.98	2884	11.7	21.9	10.2	19.2	24558	58.8	18.8
3	W	16.90	14.06	0945	30	0.75	1.48	10.53	0.62	4.39	2788	11.9	23.1	11.2	17.1	24017	[illegible].7	21.3
4	W	22.23	18.37	1030	30	0.80	2.39	13.01	0.56	3.04	2932	11.2	22.2	11.0	18.6	25657	61.8	18.4
5	W	22.57	18.94	1111	30	0.76	2.41	12.72	0.55	2.92	3027	11.2	21.9	10.7	19.0	25494	62.4	17.6
6	W	22.45	18.71	1155	30	0.70	2.43	12.99	0.54	2.86	3011	11.9	23.4	11.5	15.5	23795	59.4	18.7
7	W	22.57	18.94	1235	30	0.67	2.25	11.88	0.54	2.83	2996	10.7	20.7	10.0	21.0	26334	59.4	16.9
8	S	22.68	18.71	1320	30	0.55	2.25	12.03	--	--	3059	11.4	21.0	9.6	17.9	21549	57.0	17.5
9	W	22.79	19.16	1405	45	0.71	2.32	12.11	0.49	2.58	2932	10.6	20.0	9.0	19.9	33689	59.4	16.2
12/16-1	S	11.68	9.98	0800	30	0.24	0.95	9.52	0.66	6.59	2772	12.4	21.9	9.5	18.4	21920	58.1	16.7
2	W	11.34	9.75	0840	30	0.35	0.99	10.15	0.46	4.74	2996	12.2	22.2	10.0	19.7	24704	59.2	17.3
3	W	22.68	18.94	0925	30	0.79	2.30	12.14	0.47	2.49	3091	12.3	22.8	10.5	17.1	22516	59.2	18.3
4	S	22.68	18.94	1015	30	0.46	2.23	11.77	1.36	7.16	3091	11.8	21.2	9.4	16.1	18978	59.8	21.1
5	W	34.25	29.03	1115	30	0.62	2.86	9.85	0.56	1.94	3305	13.5	24.3	10.8	16.7	22617	57.8	21.4
6	S	34.13	28.69	1220	30	0.85	4.06	14.15	0.53	1.83	3187	6.8	23.4	16.6	15.8	32890	59.1	16.4
7	S	45.36	37.76	1305	30	1.48	5.69	15.07	0.46	1.21	3537	7.1	23.8	16.7	12.4	25968	56.8	18.3
8	W	45.36	38.67	1420	30	1.05	3.87	10.01	0.46	1.20	3123	7.6	20.2	12.6	14.1	22279	53.8	15.9
12/17-1	M	45.36	38.22	0800	40	1.56	5.62	14.70	0.60	1.58	3378	6.6	25.9	19.3	10.4	33560	57.6	17.5
2	M	34.02	27.44	0925	40	1.10	4.54	16.55	0.58	2.12	3378	--	--	--	10.2	--	--	--
3	M	22.68	18.94	1016	40	1.15	2.28	12.04	0.55	2.90	3187	--	--	--	9.7	--	--	--
4	M	11.34	9.19	1110	30	0.50	1.25	13.60	0.48	5.19	2996	6.7	24.6	17.9	10.9	24467	62.1	15.1
5	M	34.02	28.58	1210	40	0.86	3.83	13.40	0.52	1.83	3043	10.1	24.9	14.8	10.8	26725	58.4	15.7
6	M	22.68	18.26	1300	40	0.86	3.23	17.69	0.73	4.02	3250	7.7	39.2	31.5	5.3	27914	60.3	24.8
7	M	22.68	18.94	1355	40	0.77	2.46	12.99	1.43	7.57	3505	8.0	45.8	37.8	4.6	29073	60.7	30.2
12/18-1	M	45.36	38.10	0807	--	0.95	5.48	14.38	--	--	--	5.8	38.6	32.8	--	--	58.6	26.0
2	M	31.64	25.85	0900	40	1.20	3.91	15.13	--	--	--	6.5	42.3	35.8	4.4	26337	60.8	27.9
3	M	55.22	46.15	1007	40	1.47	6.22	13.48	1.12	2.44	3505	6.6	41.5	34.9	4.5	26259	58.7	28.6
4	M	34.02	31.30	1105	40	0.91	3.23	10.32	0.95	3.04	3410	7.6	43.8	36.2	4.9	29658	59.8	28.9
5	M	55.68	48.08	1200	40	1.20	6.46	13.44	1.06	2.20	3474	7.8	42.7	34.9	3.7	21590	59.6	29.2
12/19-1	W	22.91	19.16	0807	35	0.81	1.99	10.39	0.91	4.73	--	18.6	27.6	9.0	12.3	16195	59.9	28.7
2	W	22.91	19.05	0853	35	0.81	2.65	13.91	0.74	3.88	--	18.7	29.6	10.9	12.0	19136	59.6	27.9
3	W	22.68	19.16	0945	35	0.85	2.18	11.38	0.86	4.50	3282	17.7	31.6	13.9	9.0	18302	60.0	28.8
4	M	40.82	34.36	1035	35	1.14	4.83	14.06	1.46	4.25	3187	16.1	31.1	15.0	8.1	17775	58.8	28.7
5	M	12.59	10.09	1130	35	0.35	1.59	15.76	0.66	6.52	--	13.6	35.3	21.7	5.6	17778	62.8	27.6

M = 50% Wools, 50% Synthetic blends

W = 100% Wools

S = 100% Synthetic blends

Run (date - #)	Load composition	Wet load weight (kg)	Dry load weight (kg)	Reclaim cycle start time	Reclaim cycle duration (min.)	Recovered water (kg)	Recovered solvent (kg)	Kg solvent recovered/100 kg dry load weight	Emitted solvent (kg)	Kg solvent emitted/100 kg dry load weight	Maximum solvent concentration at condenser vapor inlet (ppm solvent)	Average condenser water inlet temperature (°C)	Average condenser water outlet temperature (°C)	Average condenser water temperature difference (°C)	Average condenser water flow rate (liters/min.)	Average cooling water heat gain (kilojoules)	Average drying (condenser vapor inlet) temperature (°C)	Average condenser vapor outlet temperature (°C)
12/16-8	W	45.36	38.67	1420	30	1.05	3.87	10.01	0.46	1.20	3123	7.6	20.2	12.6	14.1	22279	53.8	15.9

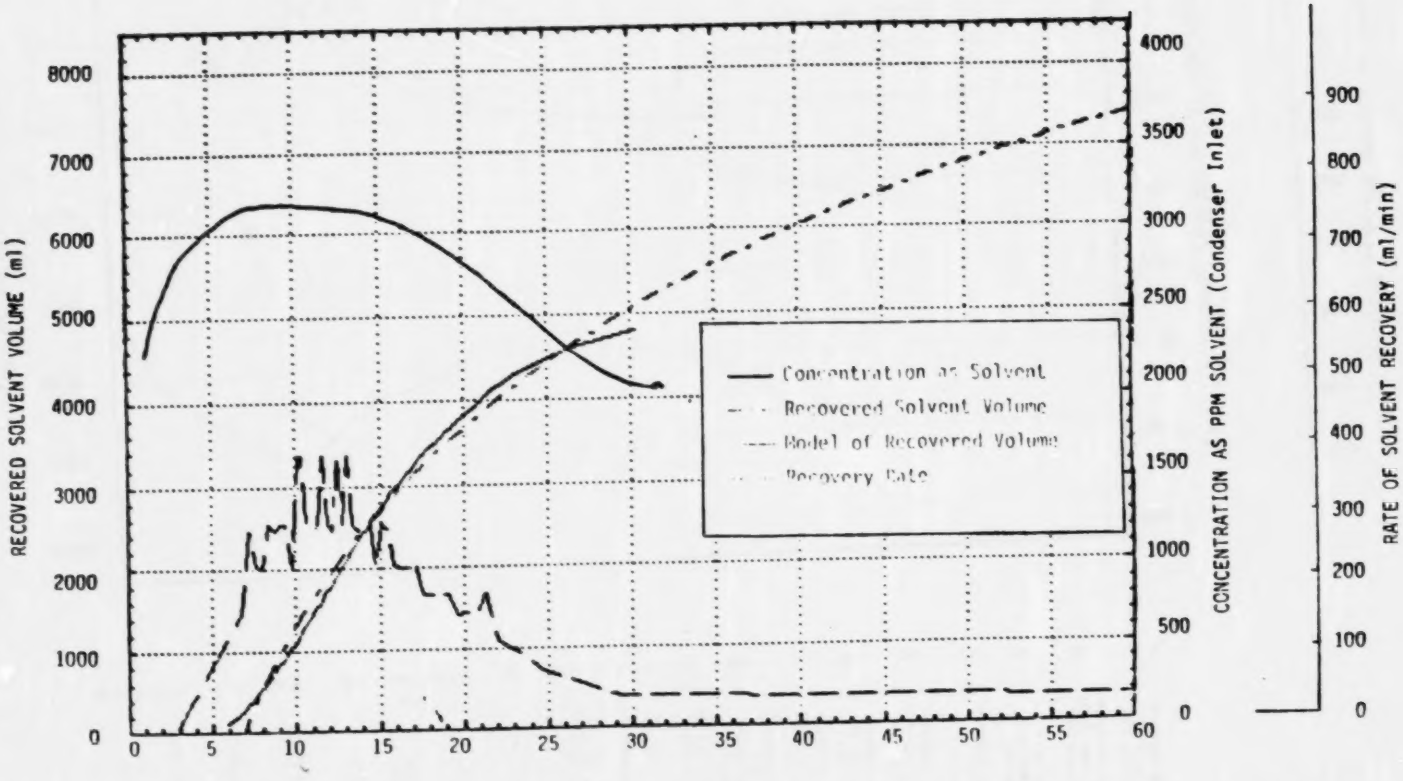

Figure C-4. Recovery and Concentration Curves for a Low-Emission Recovery Dryer Load, Plant C.

Run (date - #)	Load composition	Wet load weight (kg)	Dry load weight (kg)	Reclaim cycle start time	Reclaim cycle duration (min.)	Recovered water (kg)	Recovered solvent (kg)	Kg solvent recovered/ 100 kg dry load weight	Emitted solvent (kg)	Kg solvent emitted/ 100 kg dry load weight	Maximum solvent concentration at condenser vapor inlet (ppmv solvent)	Average condenser water inlet temperature (°C)	Average condenser water outlet temperature (°C)	Average condenser water temperature difference (°C)	Average condenser water flow rate (liters/min.)	Average cooling water heat gain (kilojoules)	Average drying (condenser vapor inlet) temperature (°C)	Average condenser vapor outlet temperature (°C)
12/17-7	M	22.68	18.94	1355	40	0.77	2.46	12.99	1.43	7.57	3505	8.0	45.8	37.8	4.6	29073	60.7	30.2

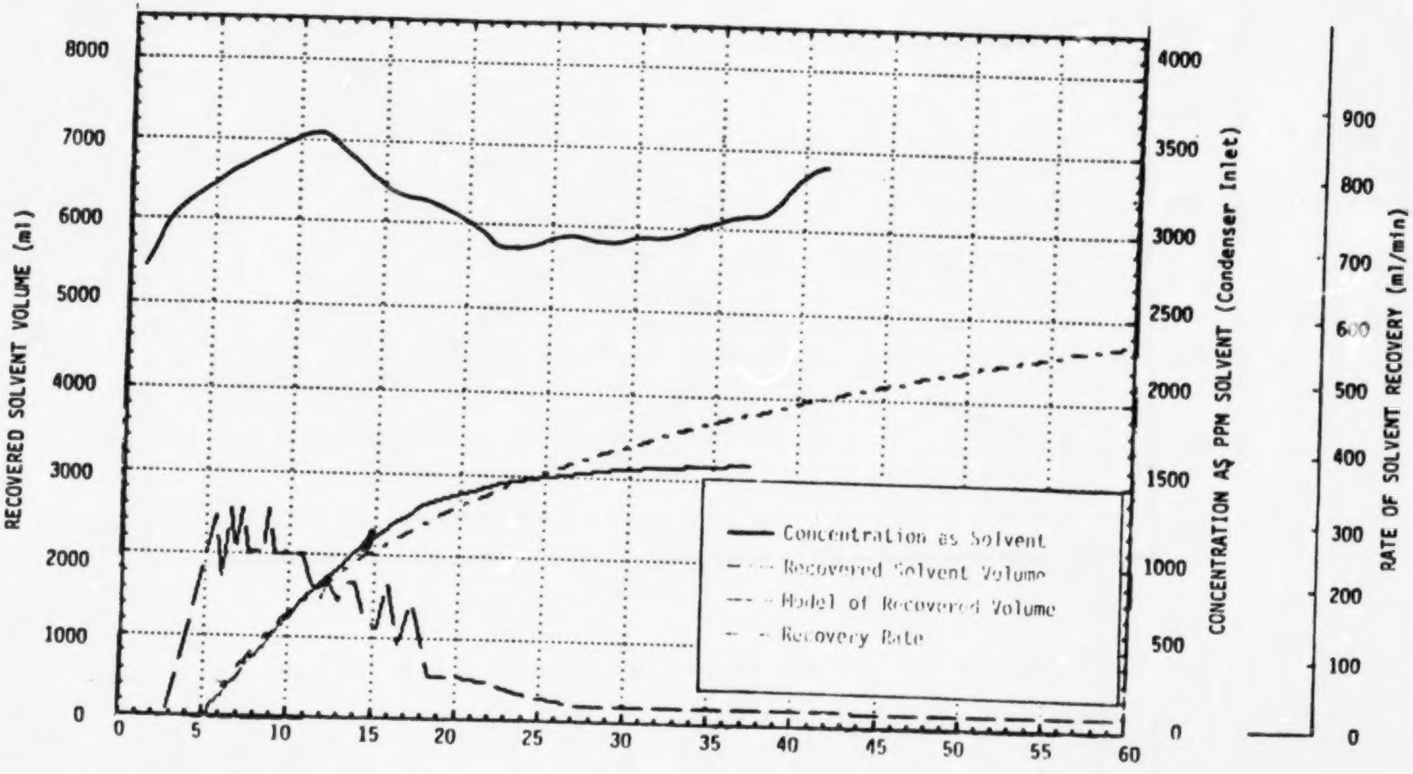

Figure C-5. Recovery and Concentration Curves for a High-Emission Recovery Dryer Load, Plant C.

Figure C-6 illustrates a dryer load with emissions approximately equal to the test average (3.2 kg VOC/100 kg articles dried). While the tumbler solvent concentration curve shows a gradual decline after a modest peak of 2,800 ppmv (as solvent), the graph of the solvent recovery rate peaks at the same rate as the low-emission load (about 400 ml/min), but the test-average emission load maintains an elevated recovery rate over a smaller portion of the recovery cycle duration.

While the measurement of high solvent concentrations was hampered by solvent vapor condensation in the FIA monitoring the condenser vapor inlet, the measurement of the solvent concentration in the dryer atmospheric exhaust was completed with a high level of confidence. The low solvent concentrations in the exhaust vapor stream precluded solvent condensation, thereby promoting the accuracy of the FIA readings.

C.4 PLANT D (CARTRIDGE FILTER)

An EPA-sponsored study was conducted to determine the rate of solvent drainage from heavily soiled cartridge filter elements and to compare the drainage rates of new and soiled cartridges. A recommendation was made for a minimum drainage time for these elements based on the total maximum solvent emission from the entire filtration system (Plaisance, 1981).

The host plant for this study was a petroleum dry cleaning facility that cleaned approximately 900 kg (2,000 lbs) of lightly soiled general apparel each week, expending about 380 liters (100 gallons) of Ashland Kwik-Dri solvent. Dry cleaning equipment used at this facility was limited to a single 27 kg (60 lb) capacity Marvel Matic washer and two 22 kg (50 lb) capacity Heubsch Originator dryers. Spent solvent was filtered and purified by a 14-element cartridge filter (Puritan Vanguard 14) which employed 12 carbon-core and 2 all-carbon filter cartridges. The carbon-core filter elements served to both remove solids and provide initial purification, while the all-carbon filter element provided final solvent purification.

The test procedure consisted of removing two filter cartridges (one carbon-core and one all-carbon) that contained heavy concentrations of lint and dirt from the cartridge filtration system. These elements, along with two new cartridge elements (one of each type), were soaked in

Run (date - #)	Load composition	Wet load weight (kg)	Dry load weight (kg)	Reclaim cycle start time	Reclaim cycle duration (min.)	Recovered water (kg)	Recovered solvent (kg)	Kg solvent recovered/100 kg dry load weight	Emitted solvent (kg)	Kg solvent emitted/100 kg dry load weight	Maximum solvent concentration at condenser vapor inlet (ppm solvent)	Average condenser water inlet temperature (°C)	Average condenser water outlet temperature (°C)	Average condenser water temperature difference (°C)	Average condenser water flow rate (liters/min.)	Average cooling water heat gain (kilojoules)	Average drying (condenser vapor inlet) temperature (°C)	Average condenser vapor outlet temperature (°C)
12/12-5	M	27.56	23.25	1353	30	0.75	2.77	11.91	0.74	3.20	2836	14.8	26.5	11.7	16.9	24795	68.3	22.5

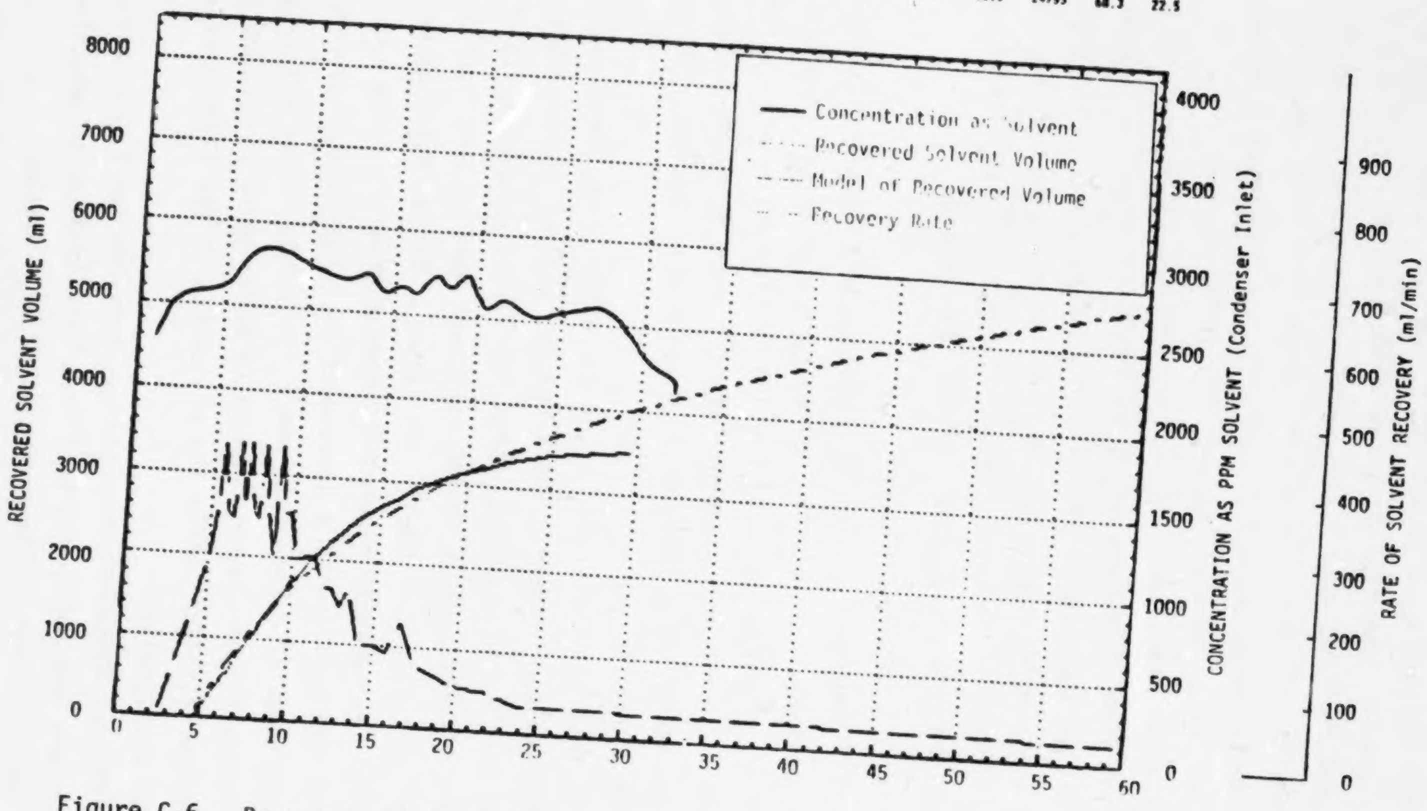

Figure C-6. Recovery and Concentration Curves for a Recovery Dryer Load with Emissions Approximately Equal to the Overall Test Average, Plant C.

sealed containers of solvent and then were allowed to drain while weight loss readings were recorded. The cartridge elements then were placed under an exhaust hood where the solvent was allowed to evaporate freely at room temperature, and and each sample cartridge was weighed twice each day for seven days.

A comparison of the percent solvent loss, as a function of drainage time between new and used cartridges, indicated that the soil and residue loadings of both used cartridges caused a lower rate of solvent drainage. The largest differences in drainage rates occurred between new and used all-carbon cartridges, while a similar comparison of carbon-core cartridges resulted in a more equal percent drainage of initial solvent content over the entire drainage period. In general, carbon-core cartridges gave up solvent at a higher rate than all-carbon cartridges over extended periods of drainage and evaporation.

The results of this test indicate that a solvent drainage duration of 8 to 12 hours (overnight) would be sufficient to produce a minimal total emissions (see Figure C-7), while being brief enough to prevent disruption of normal plant operation. The undrained system emission rate of 0.56 kg solvent per 100 kg dry weight of articles cleaned would be reduced by 37 to 40 percent after drainage durations of 8 to 12 hours, respectively. Table C-4 shows emissions from cartridges over a period of several days. Comparison of solvent retention in new and used cartridges indicates that new cartridges having no soil and residue loading would have initial (undrained) emission roughly equivalent to those of the used cartridges. Therefore, general results gained in this test could be applied to facilities having lower throughputs between cartridge replacements and/or lower soil loading.

C.5 PLANT E (VACUUM STILL WASTE AND FUGITIVE EMISSIONS)

EPA contracted a study to collect and analyze data at a large industrial dry cleaning facility to evaluate the technical and economic feasibility of reducing the solvent content of still wastes through: (a) operating procedure modifications, and by (b) installing a densiometer in the still bottom to control the boildown schedule. In addition,

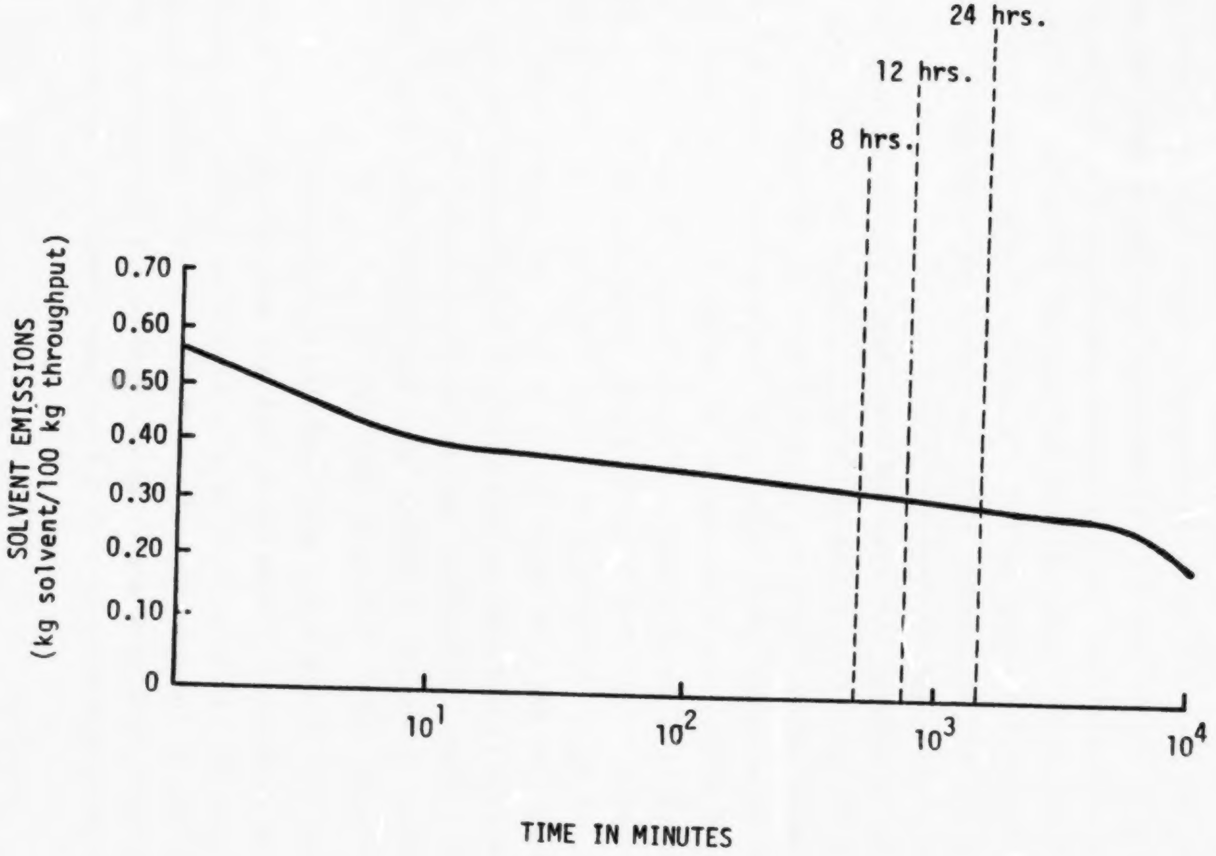

Figure C-7. Solvent Emissions for Filter Cartridges as a Function of Drainage Time, Plant D.

Table C-4. TOTAL SOLVENT EMISSIONS DUE TO DISPOSAL OF 14 FILTER CARTRIDGES (12 CARBON-CORE AND 2 ALL-CARBON) AS A FUNCTION OF DRAINAGE TIME

Elapsed drainage time	Solvent emissions (in kg solvent emitted per 100 kg of articles cleaned)	Percentage of undrained emissions
0	0.56	100
8 minutes	0.41	73
8 hours	0.35	63
12 hours	0.34	62
8.25 days	0.22	39

hydrocarbon concentrations were measured from fugitive sources within the dry cleaning plant during the test period (Jernigan and Kezerle, 1980).

The host plant for this test was a large industrial laundering and dry cleaning facility that utilized a 230 kg (500 lb) Washex washer/ extractor and a 180 kg (400 lb) Challenge-Cook dryer to clean approximately 8,700 kg (19,000 lbs) of articles of personal clothing per week. In addition, the facility had two Washex solvent stills, each with a 1,900 liter (500 gal) per hour capacity. Data were collected at the plant for this evaluation from November 5 to November 19, 1979.

Procedures used to accomplish the test objectives included the determination of the boildown time for the vacuum still and the determination of the specific gravity of the solvent/still waste mixture during distillation by using a densiometer. Plant records were examined to determine the frequency of still boildowns. In addition, fugitive solvent emission levels at various locations in the plant were measured using a Beckman 400 flame ionization analyzer (FIA).

Hydrocarbon concentrations in and around the work area in the dry cleaning facility were reported as parts per million (ppm) of propane. (A standard conversion factor from propane to petroleum solvent of 3.36 was calculated.) Emissions could be approximated only for the roof exhaust, where approximately 1.56 kg (3.43 lbs) of solvent were emitted per hour. The highest solvent vapor levels in the workplace were recorded around the washer, averaging about 3,300 ppm as propane or 980 ppm as solvent. Hydrocarbon concentrations at the clean solvent tank were an order of magnitude higher, reaching as high as 24,000 ppm as propane or 7,150 ppm as solvent.

Results of this test indicated that measuring the specific gravity of the still contents during distillation with a densiometer was not feasible or even desirable, due to the adverse thermal and mechanical effects of rapid boiling on the sensitive densiometer mechanism. However, the solvent content of the still waste generated at this petroleum dry cleaning facility could be reduced, with no adverse effects, by boiling down the stills less frequently. At the time of this test program, the stills were boiled down and the waste in the sump was discarded daily. This meant that 144 liters (38 gal), or 115 kg of still waste, containing approximately 90 percent pure solvent by volume, was discarded each day. Table C-4 records the samples of still waste that were analyzed for solvent content before and after boildown. On the first day (11-07-79) the still waste (sample VIS-4) contained more than 99 percent by volume (97 percent by weight) solvent. Still waste sample VIS-21 on the seventh day (11-14-79) represents the typical volume of solvent discarded daily at this plant and has the highest daily throughput. This sample contained approximately 90 percent by volume (91% by wt) solvent, representing a reduction of 5 percent over sample VIS-4, due to the reduced boildown frequency.

Results from solvent content analyses conducted on 11-15-79 and 11-16-79 (VIS-23 and VIS-26, respectively) showed no appreciable difference in their solvent contents. Instead of a decrease in solvent content from samples VIS-23 to VIS-26, there was actually a 2 percent increase. This increase is considered insignificant on a day-to-day basis and may be attributable to a number of factors such as a change in the type of articles cleaned, still operation, or a slight variation in laboratory procedures for analyzing the still waste.

Still waste was allowed to accumulate for 10 days (11-09-79 to 11-19-79) before the still was boiled down again. On the last day of testing, the still was boiled down and sample VIS-30 was analyzed for its solvent content. This sample contained 25 percent less solvent, on a mass basis, than VIS-4 and 21 percent less solvent than VIS-26, as shown in Table C-5.

The analytical procedures used to determine the solvent content in each sample involved determining the moisture content by the Carl-Fisher Method and gravimetrically determining (at 103°C) the nonvolatiles in the samples. The solvent content then was determined by a process of elimination, in which the quantity of nonsolvent components was determined and then was subtracted from the total sample mass.

An alternate method to decrease solvent losses would be to reduce the total volume of still waste, by eliminating the inactive space in the still below the steam chest. In the tested still design, liquid

Table C-5. RECORD OF STILL WASTE BOILDOWN SAMPLES

Date	Military time	Sample no.	Throughput (kg)	Still waste (kg)	Weight percent solvent in waste	Solvent loss with waste (kg)	(kg) solvent loss/ 100 kg articles cleaned
11/07/79	0730	VIS-4	1360	115	97.40	112	8.20
11/14/79	1245	VIS-21	1588	115	92.20	106	6.70
11/15/79	1230	VIS-23	1360	115	91.30	105	7.70
11/16/79	1200	VIS-26	1425	115	93.00	107	7.50
11/19/79	1320	VIS-30	1425	115	73.00	84	5.90

below the steam chest did not receive sufficient heat to vaporize during boildown. This liquid, which contained a high concentration of solvent, was discharged daily after boildown. The more frequenty the still was boiled down, the greater the amount of solvent discarded with the wastes.

A fugitive VOC emission rate of 1.56 kg per hour was recorded (11-09-79) during the course of a 6-hour dry cleaning day when approximately 1,360 kg (3,000 lbs) of pants were dry cleaned. This equates to 227 kg of articles cleaned per hour. Thus, the ratio of the mass of fugitive solvent emitted per hour to the mass of articles cleaned per hour was 0.687 kg of fugitive VOC emitted per 100 kg of articles cleaned. Two access doors were open (front and rear of the dry cleaning area) during the fugitive emissions test. It is assumed that the recorded fugitive emissions rate would have been higher if these doors were closed.

C.6 PLANT E (CARBON ADSORPTION)

EPA contracted the evaluation and demonstration of carbon adsorption technology at an industrial dry cleaning facility to determine the effectiveness of carbon adsorption in controlling VOC emissions (Lutz et al., 1980). It consisted of fitting a prototype carbon adsorption unit, purchased from VIC Manufacturing Company of Minneapolis, Minnesota, to the dryer exhaust of a petroleum solvent industrial dry cleaning dryer; operating the system to collect performance data; and evaluating the economics of operation at this establishment.

The host dry cleaning plant was a large, industrial facility utilizing a 230 kg (500 lb) Washex washer/extractor and a 180 kg (400 lb) Challenge-Cook dryer to process approximately 8,700 kg (19,000 lb) of general apparel per week. This throughput represents about 50 percent of the 8-hour capacity of the dry cleaning dryer. Data were developed to determine the effect of the different utilization rates on the various parameters under evaluation. After installation of the carbon adsorption unit, testing was conducted at the facility from July 24, 1978 to March 23, 1979.

Test procedures used during the carbon adsorption test program included a determination of hydrocarbon concentrations by continuously sampling the gas streams to and from the carbon adsorption unit. This was accomplished using two Beckman 400 flame ionization analyzers (FIA). Both the inlet and exhaust gas stream flow rates were continuously monitored, as were the temperatures of the various liquid and gas streams. Other parameters measured during the test program included: electricity consumption, natural gas consumption, water usage, steam flow rate to adsorption unit, and solvent recovery rate. In addition, samples of solvent and samples of carbon from the carbon bed were analyzed infrequently during the test period.

The carbon adsorber system (see Figure C-8) was initially operated in strict compliance with the recommendations and instructions of the adsorber manufacturer and his field representatives. Early in this test period, it became apparent that the adsorption system had been overdesigned, resulting in removal efficiencies far in excess of the specified performance guarantee of 90 percent solvent removal on a 24-hour average. The test program was, therefore, amended to include an evaluation of changes to the design and operating procedures for the carbon adsorption system. Various design parameters were modified to determine their effect on the performance and cost of the adsorption system. From these studies, an optimized system was established for use in evaluating the performance, cost, and cost effectiveness of utilizing carbon adsorption technology for the reduction of VOC emissions from petroleum dry cleaning plants.

The following alterations to the original adsorber design resulted from the optimization: (1) the lint filter area was increased by 80 percent to facilitate daily cleaning; (2) the blower that forces the dryer exhaust through the adsorber was modified to operate only when the dryer was running, rather than continuously; (3) the original system of three carbon beds was reduced to two beds; (4) desorption steam pressure, flow rate, and duration were optimized at 103 kilopascals, 590 kg/hr, and 60 minutes, respectively; and (5) the adsorber inlet (dryer exhaust) vapor cooler was eliminated, because dryer exhaust temperatures were insufficient to damage the carbon beds.

The test-average hydrocarbon emission reduction efficiency for the optimized design (applied to the dryer exhaust) was 95 percent, and varied from 93 percent for a plant with 100 percent utilization to

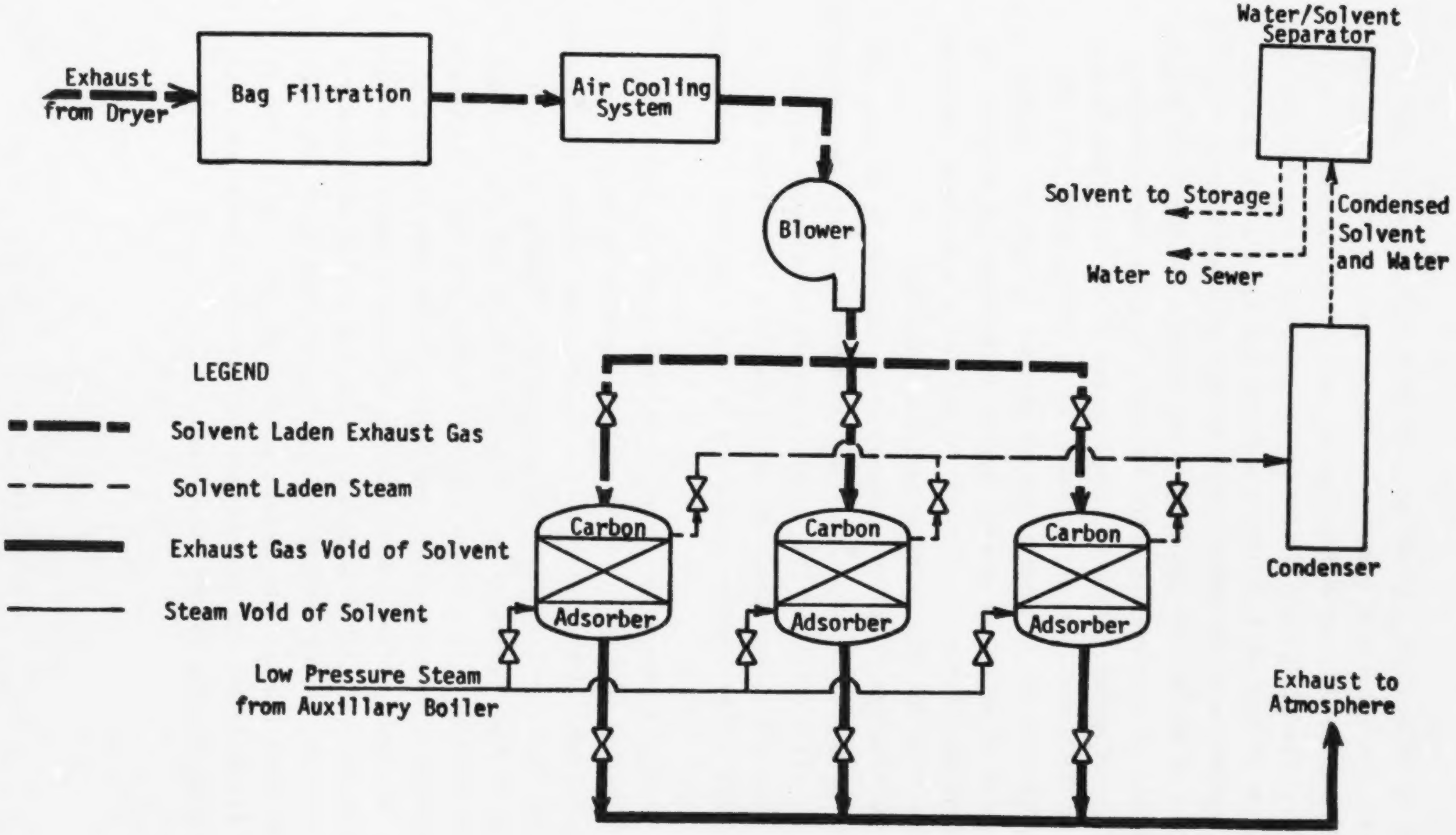

Figure C-8. Carbon Adsorption System Schematic, Plant E.

97 percent at 25 percent utilization (see Table C-6). Capital costs for this system, including site preparation and equipment installation, are estimated at $128,000 (mid-1978 dollars). Cost effectiveness, defined as the annual operating cost divided by the quantity of emission reduction, is a function of equipment utilization rates, and additionally exhibits a strong dependence on the market value of the recovered solvent. A solvent cost of $0.16/liter ($0.61/gal) was assumed for the basic analysis, but the effect of increases in petroleum costs on annualized operating costs was investigated. The cost effectiveness of the optimized design was $560/Mg ($510/ton), and was estimated as $1,090/Mg ($980/ton) and $220/Mg ($200/ton) for 25 percent and 100 percent utilization, respectively. When the value of petroleum solvent reaches $0.60/liter ($2.30/gal), the optimized system (50 percent utilization) will have zero annual operating costs, neglecting the rise in other operating expenses.

The test-average of solvent recovery efficiency was 84 percent, and varied from 75 to 94 percent. The disparity between the emission reduction and recovery efficiencies of the solvent entering the adsorber was not accounted for. This discrepancy was attributed to a combination of fugitive leaks in the adsorber system and to an accumulation of measurement errors.

The results of this project demonstrate the technical feasibility of applying carbon adsorption technology to reduce the emission of hydrocarbon solvents from dryer exhausts at petroleum solvent dry cleaning plants. The cost effectiveness of this technique, $560/Mg ($510/ton), is expected to drop significantly as the value of the reclaimed solvent, a petroleum distillate, increases. Even at its present cost effectiveness, carbon adsorption is economically comparable with the cost of emission reduction required in other industries. An additional benefit, provided by the application of carbon adsorption technology to the petroleum dry cleaning industry, is the reduction in overall consumption of petroleum products by these plants. The demonstration plant recovered solvent at a rate of 61,000 liters (16,000 gal) per year which otherwise would have to be replaced with new solvent purchases.

Table C-6. SUMMARY OF DRY CLEANING CARBON ADSORPTION OPTIMIZATION PROGRAM OPERATING DATA, PLANT E

Julian date (1978)	Electrical consumption of system kWh	Natural gas consumption of boiler ft3	Water consumption of boiler (l)	Decanted water to sewer (l)	Water flow to tower cooler (l)	Water flow to condenser (l)	Solvent introduced adsorber (l)	Solvent air emissions from adsorber (l)	Recovered solvent (l)	No. dry cleaning cycles (per_day)	% Recovered (weekly)	Emissions reduction (weekly)
338	207	210	2687	2650	3179	73107	270	24.1	189	14		
339	267	99	1893	757	3142	133939	280	6.1	174	15		
340	311	102	1552	1136	4883	147237	241	15.5	159	15	.75	95.2
341	311	99	1207	757	4883	143530	244	11.9	193	13		
342	266	91	1363	757	4466	130960	212	2.5	216	12		
345	261	93	1211	1136	4883	127100	270	6.5	189	13		
346	312	99	1476	757	4504	136260	284	13.7	201	15		
347	217	93	1325	1136	4542	117710	226	10.1	220	12	.83	96.3
348	265	105	1628	757	4050	120740	270	12.5	220	13		
349	173	93	1363	1136	3104	87606	234	5.3	235	12		
353	223	96	1552	757	2157	215745	147	4.0	167	9	.89	96.7
354	265	93	1741	1136	4315	123310	201	7.2	144	12		
1979												
003	220	108	1476	1136	3709	93110	123	2.2	144	7		
004	215	93	1237	757	4921	127550	180	3.2	139	11	.90	97.9
005	265	99	1207	1136	3671	117710	241	5.8	155	12		
008	353	93	1325	757	3407	162380	310	23.0	233	16		
009	218	102	1409	757	2460	113550	288	15.1	243	13		
010	261	93	1211	1136	3104	100680	259	14.1	224	14	.87	94.9
011	203	93	1476	757	6737	91990	241	7.5	238	13		
012	217	91	1325	757	3407	113930	244	9.0	229	12		
015	216	109	1400	757	2990	126040	226	11.1	229	13		
016	262	112	1249	757	4012	140420	292	17.6	224	16		
017	260	106	1249	757	4126	133530	342	25.6	243	17	.90	94.0
018	215	122	1400	757	3671	126040	270	16.5	262	13		
019	219	116	1363	757	3369	103330	216	9.7	257	12		
022*	221	0	0	0	2339	107120	226	6.5	0	13		
023*	172	0	0	0	2729	96900	270	76.2	0	14		
024*	171	184	2309	2271	4201	110900	90	40.3	449	5	.83	87.0
025	263	93	1211	379	4050	129070	306	16.9	267	14		
026	260	96	1363	757	4542	136640	292	14.3	265	15		
029	264	102	1249	757	4277	140420	280	10.5	265	13		
030	259	88	1173	757	4466	162760	292	15.9	269	15		
031	260	102	1287	757	1438	140045	306	36.7	299	15	.94	92.9
032	171	99	1249	757	2271	114310	230	19.4	227	12		
033	262	96	1211	379	4693	140420	259	14.1	227	15		

(continued)

Table C-6. Concluded

Julian date (1978)	Electrical consumption of system kWh	Natural gas consumption of boiler ft3	Water consumption of boiler (l)	Decanted water to sewer (l)	Water flow to tower cooler (l)	Water flow to condenser (l)	Solvent introduced adsorber (l)	Solvent air emissions from adsorber (l)	Recovered solvent (l)	No. dry cleaning cycles (per day)	% Recovered (weekly)	Emissions reduction (weekly)
036	168	91	1249	757	4769	111280	223	9.3	227	12		
037	259	96	1325	1136	5261	137400	288	8.6	223	13		
038	258	91	1022	757	2385	149510	288	8.3	227	14	.85	96.6
039	259	88	1173	379	4315	134370	288	11.5	227	13		
040	211	91	1136	1136	2233	106360	266	8.6	250	12		
043*	169	0	0	0	1211	88191	310	11.5	0	13		
044*	220	0	0	0	1060	85920	306	105.7	0	14		
045*	218	0	0	0	757	102195	313	298.8	0	15	.54	65.8
046*	123	263	3225	3028	2271	88948	0	0	448	0		
047	312	93	1211	757	1855	128690	295	2.5	213	13		
051	218	91	1249	757	1476	104088	262	5.0	244	12		
052	307	96	1173	757	1476	142695	389	21.9	254	19	.76	94.2
053	212	96	1211	757	1590	115064	356	22.6	278	16		
054	308	88	1136	379	1703	128312	367	30.2	269	17		
057	218	93	1211	757	1623	113550	377	17.3	279	14		
058	257	93	1211	757	2309	134368	356	20.5	259	15	.80	95.7
059	216	96	1173	757	1703	101817	294	9.3	270	14		
060	264	79	1363	757	1249	114307	292	9.7	252	13		
064	211	91	1249	757	3066	119228	252	10.1	237	11		
065	212	71	871	379	2914	102195	310	6.8	224	14		
066	256	71	1022	757	3104	123013	302	41.5	225	15	.83	95.8
067	216	71	984	379	1703	96139	205	4.0	210	10		
068	214	65	824	757	1855	167335	294	8.6	239	12		
071	212	62	946	379	2006	114686	292	27.0	185	14		
072	215	76	946	379	1514	119606	274	20.5	255	13	.81	91.8
073	263	74	984	379	1893	115064	266	18.7	237	14		
074	213	76	1211	757	1514	118092	256	23.4	208	13		
078	218	82	795	379	871	108630	277	12.9	220	13		
079	219	76	946	757	1022	97275	230	11.5	214	11		
080	264	82	1098	379	984	126040	288	38.9	167	15	.75	89.6
081	125	68	871	757	946	77590	198	22.3	145	10		
082	211	76	1022	379	1590	114690	220	40.7	162	12		

*Breakthrough test.

At the conclusion of the program demonstrating carbon adsorption technology, EPA contracted three additional tests of the system to evaluate the long-term performance of the carbon adsorber. These tests were conducted on March 27, 1980, June 18, 1980, and January 14, 1981 (Kezerle, 1981b). They consisted of measurements of hydrocarbon concentrations in the gas steams at the inlet and outlet of the adsorber, measurements of exhaust gas flow rate, analyses of carbon and solvent samples, and qualitative observations on the condition and operation of the system. Hydrocarbon concentrations were measured with one Beckman 400 flame ionization analyzer (FIA) which was employed at different times on both the inlet and outlet streams. Flow rate measurements were made on the inlet stream with an S-type pitot probe. The carbon adsorber system was operated in the optimized mode which, in contrast to the original mode of operation, included a larger lint filter, blower operation only during dryer operation, adsorption by only two carbon beds instead of three, and elimination of the vapor cooler.

The results of each of the three long-term tests indicated that the carbon beds were still able to adsorb over 90 percent of the hydrocarbons that entered them (Kezerle, 1981b). The hydrocarbon adsorption efficiencies for the three tests, in chronological order, were 96.3 percent, 93.5 percent, and 96.4 percent. The rate of solvent vapor entering the adsorbers varied widely from 13.4 pounds of solvent per 100 pounds of material on March 27, 1980, to 15.3 pounds per 100 pounds of material on June 18, 1980, and only 11.0 pounds per 100 pounds of material on January 14, 1981. This variation in detected solvent flow rate at the inlet was due to variations in the system's condition between tests, primarily blockages in the ducts and carbon beds. The rates of solvent recovery during each of the tests were 55.6 percent on March 37, 1980, 70.6 percent on June 18, 1980, and 94.5 percent on January 14, 1981. The variations in these recovery rates were due to variations in the procedures used to desorb and dry the carbon beds. Desorbing times that were too short and steam pressures that were too low were found to be the main reasons for poor solvent recovery. Measured solvent recovery efficiencies were always below the measured solvent adsorption efficiencies. Fugitive losses that might account for these differences were identified but not quantified. They include solvent vapor leaks during and between dryer runs, solvent vapor losses during the desorption and drying of the carbon beds, and liquid solvent losses associated with desorption and decanting.

In an effort to certify the carbon adsorption system as being in compliance with the local environmental regulation, a performance tests was conducted by the South Coast Air Quality Management District (SCAQMD) on November 26, 1980 (Kezerle, 1982). During that test, SCAQMD measured a hydrocarbon adsorption efficiency for the carbon beds of only 81 percent. This was significantly below the required minimum limit of 90 percent. Because all of the tests sponsored by the EPA had recorded an adsorption efficiency of over 90 percent, the reasons for SCAQMD's lower value came into question. The EPA contended that the poor performance of the system was due to poor operating procedures during and immediately preceding SCAQMD's test. The question of agreement between differing test methods also arose. SCAQMD had used the EPA Method 25 while EPA had used the EPA Method 25a in all tests.

In an attempt to resolve these matters, the EPA arranged for simultaneous tests of the system's performance. These tests were conducted on June 3, 1981, by EPA and SCAQMD (Kezerle, 1982). EPA employed EPA Method 25A, as described above, and SCAQMD employed EPA Method 25. (Method 25 uses total combustion analysis of samples to determine total flow rates of organics.) EPA sampled all 13 dryer loads run during the day while SCAQMD sampled only one run. For the corresponding dryer run both methods measured a solvent adsorption efficiency of about 97 percent. The close agreement between the different test methods and the high adsorption efficiency indicated by the results support the conclusion that SCAQMD's earlier test measured a non-characteristic period of performance for this system, probably due to poor operating procedures. EPA's additional test data for the other dryer runs indicated an average solvent adsorption efficiency for the entire day of 93 percent. Also, EPA conducted a material balance on the solvent passing through the entire carbon adsorption system and calculated the maximum expected solvent recovery efficiency of this system at about 82 percent. This value agrees well with the test-average value measured during the demonstration phase.

Results of the three long-term tests and the simultaneous EPA/SCAQMD test indicated the carbon that was installed in the system in July 1978 has maintained, through June 1981, the capability of adsorbing over 90 percent of the solvents vapors introduced to it. It was further shown, however, that the maximum solvent recovery efficiency of the system is approximately 82 percent. Efficiencies below these two target values have historically been due to poor operation and maintenance of the system.

C.7 PLANT F (STILL WASTE AS BOILER FUEL)

EPA conducted an evaluation of a functioning still waste burning system at an industrial dry cleaning facility that cleans about 7,300 kg of uniforms, shirts, and wiping towels per week. The test was conducted on May 20 and 21, 1980. Samples of still waste, solvent, and fuel oil were analyzed, the composition of the boiler combustion exhaust was analyzed, and the boiler was examined for possible damage resulting from burning a mixture of still waste and fuel oil. Additionally, the costs and savings resulting from using still waste as an auxiliary boiler fuel were determined (Kezerle, 1981a).

The plant's steam boiler was converted in 1978 with the aid of an outside engineering firm to burn waste oil accumulated in vacuum stills. At that time, 400 to 500 gallons of waste oil, similar to #4 oil, was collected each week. (The amount has since dropped to about 100 gallons per week because the plant no longer cleans wiping towels.) This facility was chosen because it had been burning still waste continuously for two years and thus any deterioration in the condition of the boiler due to the still waste should have been apparent.

Data were collected in four distinct areas: still waste chemical analysis, boiler stack emissions, boiler internal condition, and system costs. Test results indicated that the composition of the still waste was quite similar to #4 oil (see Table C-7). The concentrations of sulfur and nitrogen were within the legal limitations as set by the state of Connecticut, and no hazardous or corrosive comounds were found in significant quantities. Hydrocarbon emissions while burning #4 oil were less than 1 ppm as methane. Hydrocarbon emissions from the boiler

Table C-7. COMPARISON OF OIL, STILL WASTE, AND SOLVENT, PLANT F

Parameters	Typical #4 Oil	Solvent Mineral Spirits*** 145 - EC	Leasetex Still Waste 5/20/80	Leasetex* Boiler Fuel 5/20/80	Leasetex** Boiler Fuel 5/21/80
Heat value (Btu/lb)	18,280 - 19,400	–	19,691	19,397	18,963
Density (lbs/gal)	7.78	6.48	6.831	7.448	7.137
Viscosity (s.u.s. @ 100°F)	130 (60 - 300)	–	35	61	38
Flash point (c.o.c. °F)	–	112°F	140°F	266°F	172°F
Fire point (c.o.c. °F)	–	–	147°F	284°F	180°F
Nitrogen (wt.%)	–	–	0.15	0.12	0.13
Sulfur (wt.%)	0.8 (0.2 - 2.0)	–	0.17	0.40	0.31
Chlorine (wt.%)	–	–	0.32	0.09	0.17
Ash (wt.%)	0.03 (0 - 0.1)	–	0.12	0.074	0.065
Moisture (wt.%)	0.2 (0 - 1.0)	–	<0.1	<0.1	<0.1
Sodium	–	–	56.1 ppm	51.2 ppm	47.1 ppm
Vanadium	–	–	1.03 ppm	59.6 ppm	18.8 ppm

* 7.3% Still Waste by volume
** 37.5% Still Waste by volume
*** Manufactured by Shell

stack while burning two different still-waste/fuel oil mixtures increased with an increase in the concentration of still waste in the boiler fuel. Some levels in range of the 40 ppm (as methane) recorded while burning a mixture of 37 percent still waste in #4 oil. Evidence suggested, however, that this increase was due only to the heaviest hydrocarbons in the mixture. This increase in emissions could have been reduced by separating and removing the heavy hydrocarbons through settling before burning. The internal condition of the boiler was judged to be excellent by an independent boiler inspector when examined after the tests. It showed no signs of corrosion or deterioration. Available cost data on the system show it to be an economical way of controlling these types of still wastes where an appropriate steam boiler exists. The total installed capital cost for the still waste storage and burning system was about $6,100 in 1976. For the first five months of 1980, still waste was generated at a rate of 350 gallons/month. At a price of $0.85 per gallon for #4 oil, substitution of still waste for part of the plants fuel needs would allow the still waste combustion system to pay for itself in two years.

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APPENDIX D. ENVIRONMENTAL AND COST IMPACTS OF EXEMPTION LEVEL AS APPLIED TO REGULATORY ALTERNATIVE III

The economic impact analysis for Regulatory Alternative III presented in Section 9.2 has revealed that only plants with weekly throughputs of 1,150 kilograms (2,540 pounds) or more can support the financing of recovery dryers with no resulting increase in annualized costs. Therefore, Regulatory Alternative III has been modified to impact only those petroleum dry cleaning plants that consume 17,800 liters (4,700 gallons) or more of petroleum solvent. For new plants, the solvent consumption rate to be compared to the cutoff level to determine the applicability of the standard will be projected based on the manufacturer's rated dryer capacity and a derived factor of 212 liters (56 gallons) of petroleum solvent per kilogram (pound) of articles cleaned. For new dryers in existing plants that are not expanding their dryer capacity, the consumption rate will be based on the solvent consumption in the previous year (from solvent purchase receipts). For plants that are expanding existing dryer capacity, the solvent consumption rate will be based on the previous year's consumption and the ratio of the manufacturer's rated dryer capacity (total for the plant) before and after the proposed modification. For a discussion of Regulatory Alternative III, refer to Chapter 6. Regulatory Alternative III with the described modification is discussed in this appendix. Regulatory Alternative III is representative of the recommended standards limiting VOC emissions from new, reconstructed, and modified petroleum solvent dry cleaning facilities.

D.1 MODIFIED REGULATORY ALTERNATIVE III

Under modified Regulatory Alternative III, an affected petroleum dry cleaning plant that is replacing an existing dryer or adding a new dryer is required to install, operate, and maintain a solvent recovery dryer. This requirement pertains only to petroleum dry cleaning plants that are projected to consume 17,800 liters (4,700 gallons) or more of petroleum solvent per year. The use of cartridge filters would be required for any plant with new, modified, or reconstructed solvent filtration systems. Modified Regulatory Alternative III would also require prompt repair of leaks from dryers, washers, solvent filtration systems, settling tanks, vacuum stills, and the pipes and ducts associated with the installation and operation of these devices. For the purpose of this standard, each of these items of equipment is considered a separate affected facility. As such, the items of equipment listed above must conform to the standards only if that specific item is new, modified, or reconstructed.

D.2 ENVIRONMENTAL IMPACTS OF MODIFIED REGULATORY ALTERNATIVE III

The environmental and energy impacts associated with the implementation of modified Regulatory Alternative III are discussed in this chapter with respect to air quality, water quality, solid waste, and energy consumption. Both beneficial and adverse impacts are assessed.

D.2.1 Air Emissions Impacts

The model plant VOC emission rates resulting from the application of the control techniques required under modified Regulatory Alternative III are given in Table D-1. The small and medium commercial model plants have annual solvent consumptions less than the exemption level and, consequently, are not required to install recovery dryers under modified Regulatory Alternative III. These model plants utilize standard dryers which represent the largest single source of VOC emissions in a plant. As a result, these plants have the highest aggregate emission rates of the five model plants with nominal rates of 23 kilograms VOC emitted per 100 kilograms of articles cleaned (ranging from 16 to 37 kilograms). The large industrial model plant and the small industrial model plant (omitting filtration) have the lowest modified Alternative III emission rates with nominal rates given as 7.5 kilograms VOC emitted per 100 kilograms of articles cleaned. The range of emission rates is higher for the small industrial model plant (ranging from 2.7 to 8.5 kilograms) because filtration was assumed to be in use, whereas large industrial model plants were assumed to omit filtration thus eliminating a source of VOC emissions which lowers the range of emission rates (ranging from 2.2 to 17.5 kilograms). Large commercial model plants have modified Alternative III emission rates identical to those

Table D-1. MODEL PLANT EMISSION RATES FOR MODIFIED REGULATORY ALTERNATIVE III
(emission rates in kilograms of VOC emitted per 100 kilograms of articles cleaned)

Model plant[e]	Standard dryer	Recovery dryer	Cartridge filter	Miscellaneous emissions[f]	Plant total
SC	14-28 (18)[a]	g	0.5-1 (1)	1.5-8 (4)	16-37 (23)
MC	14-28 (18)	g	0.5-1 (1)	1.5-8 (4)	16-37 (23)
LC	b	0.7-9.5 (3.5)	0.5-1 (1)	1.5-8 (4)	2.7-18.5 (8.5)
SI	b	0.7-9.5 (3.5)	0.5-1 (1)	1.5-8 (4)	2.7-18.5 (7.5)[d] (8.5)
LI	b	0.7-9.5 (3.5)	c	1.5-8 (4)	2.2-17.5 (7.5)

[a] Numbers in parentheses are nominal values representing an overall emission rate (either an average of test data or a value widely accepted in the industry).

[b] Not applicable.

[c] Large industrial plants normally omit filtration.

[d] Small industrial plants sometimes omit filtration with heavy soil loading.

[e] SC = small commercial
MC = medium commercial
LC = large commercial
SI = small industrial
LI = large industrial.

[f] Miscellaneous includes vacuum stills, settling tanks, and other fugitive emission sources.

[g] Recovery dryers not required due to the exemption limit.

of the small industrial plant using cartridge filtration (emission rates ranging from 2.7 to 18.5 kilograms, with a nominal value of 8.5 kilograms VOC per 100 kilograms of articles cleaned).

Annual VOC emissions and emission reductions in the five model plants under Regulatory Alternative I and modified Regulatory Alternative III are illustrated in Table D-2. The model plant emission rates for modified Regulatory Alternative III are developed in Section D.1 and the model plant emission rates for Regulatory Alternative I are developed in Chapter 6. These model plant emission rates are multiplied by the model plant annual throughputs to derive the model plant annual VOC emissions. Ranges are used to illustrate that significant variations in VOC emission rates can occur due to variations in operating procedures. Under Alternative I (baseline or existing controls), the small commercial model plant has the lowest annual emission range (2.2 to 5.2 megagrams VOC per year) and the large industrial model plant has the highest range (98.4 to 229.0 megagrams VOC per year). Under modified Alternative III, annual emissions range from 2.2 to 5.2 megagrams VOC per year in the small commercial model plant and from 14.0 to 111.0 megagrams per year in the large industrial model plant. Emission reductions resulting from the implementation of modified Alternative III relative to Alternative I (baseline) are also presented in Table D-2. Emission reductions are achievable under modified Alternative III because of the requirement to utilize recovery dryers in place of standard dryers. The small and medium commercial model plants have no emission reductions under modified Alternative III because these model plants are exempted from the requirement of installing recovery dryers. Emission reductions are highest under modified Alternative III in large industrial model plants with reductions of 84.4 to 118.0 megagrams VOC per year.

Cumulative nationwide VOC emissions associated with Regulatory Alternative I and modified Alternative III were derived by multiplying the cumulative number of affected model plants existing through each year, given in Table D-3, by the appropriate model plant VOC emissions given in Table D-2. The projected number of affected model plants given in Table D-3 for ten years for the five model plant categories were derived from the 1979 nationwide plant population data given in Table 6-1. The projected number of affected plants in each model plant category was

Table D-2. ANNUAL VOC EMISSION IMPACTS OF MODIFIED REGULATORY ALTERNATIVE III IN THE FIVE MODEL PLANTS

Model plant (throughput in kg/yr)	Regulatory Alternative annual VOC emissions in Mg VOC/yr		Modified Regulatory Alternative III VOC emission reduction from baseline,[c] Mg VOC/yr
	I	III[d]	
Small commercial (14,000)	2.2-5.2 (3.2)[a]	2.2-5.2 (3.2)	none
Medium commercial (32,000)	5.1-11.8 (7.4)	5.1-11.8 (7.4)	none
Large commercial (82,000)	13.1-30.3 (18.9)	2.2-15.2 (7.0)	10.9-15.2 (11.9)
Small industrial (182,000)	28.2-67.3 (40.0)[b] (41.9)	4.9-33.7 (13.7)[b] (15.5)	24.2-33.7 (26.3)[b] (26.4)
Large industrial (635,000)	98.4-229 (140)	14.0-111 (47.6)	84.5-118 (92.4)

[a] Values in parentheses are based on nominal emission rates.

[b] Small industrial plants sometimes omit filtration with heavy soil loading.

[c] Baseline is Alternative I.

[d] Modified Regulatory Alternative III.

Table D-3. PROJECTED NUMBER OF AFFECTED PLANTS OVER TEN YEARS FOLLOWING PROPOSAL OF THE STANDARDS

	Year	Small commercial	Medium commercial	Large commercial	Small industrial[b]	Large industrial[c]
Total number of existing plants nationwide in:						
	1979	600	4,150	1,400	60	170
	1980	600	4,150	1,400	61	172
	1981	600	4,150	1,400	61	173
Additional number of affected plants nationwide in:						
	1	20	138	47	2.6	7.5
	2	20	138	47	2.7	7.5
	3	20	138	47	2.7	7.6
	4	20	138	47	2.7	7.7
	5	20	138	47	2.7	7.8
	6	20	138	47	2.8	7.8
	7	20	138	47	2.8	7.9
	8	20	138	47	2.8	8.0
	9	20	138	47	2.8	8.1
	10	20	138	47	2.9	8.2

[a] Based on zero growth rate in commercial plants, 1 percent growth rate in industrial plants, and an expected equipment life of 30 years for dryers and vacuum stills.

[b] The average number of additional affected plants per year is approximately 3.

[c] The average number of additional affected plants per year is approximately 8.

derived based on a zero percent growth rate for commercial plant, a 1 percent growth rate for industrial plants, and a 30 year equipment life which is interpreted as an annual replacement rate of 3.33 percent.

Cumulative nationwide VOC emissions are presented in Table D-4 for each model plant category for the ten years following proposal of the standards. Because of the larger number of plants, the commercial source category produces a larger quantity of nationwide VOC emissions than the industrial source category. The largest single source of VOC emissions is the medium commercial category which produces the highest cumulative nationwide ten-year emissions (38,700 to 89,600 megagrams VOC under both Alternative I and modified Alternative III). However, small and medium commercial categories are exempt from mandatory recovery dryer installation under modified Alternative III and consequently, produce no VOC emission reduction. Of the three model plant categories not exempted from mandatory recovery dryer installation, the largest source of VOC emissions is the large industrial model plant category. This category produces cumulative nationwide ten-year emissions of 43,300 to 101,000 megagrams under Alternative I and 6,160 to 48,800 megagrams under modified Alternative III. The ten-year cumulative nationwide VOC emission reductions for the large industrial model plant category due to the implementation of modified Alternative III amount to 37,100 to 52,200 megagrams VOC. The small industrial model plant category has the lowest annual VOC emissions of the three categories subject to the recovery dryer requirement. This category produces cumulative nationwide ten-year emissions of 4,650 to 11,100 megagrams VOC under Alternative I and 809 to 5,560 megagrams VOC under modified Alternative III. The implementation of modified Alternative III results in ten-year cumulative nationwide emission reductions of 3,840 to 5,540 megagrams VOC in the small industrial model plant category. The small industrial model plant category produces the least VOC emissions because this model plant category includes the least number of plants. The cumulative nationwide ten-year VOC emissions for the aggregate industry are 123,000 to 286,000 megagrams under Alternative I and 53,800 to 189,000 megagrams under modified Alternative III. The implementation of modified Alternative III results in ten-year cumulative nationwide VOC emission reductions of 69,200 to 97,000 megagrams VOC for the aggregate industry.

Table D-4. CUMULATIVE NATIONWIDE VOC EMISSIONS AND NATIONWIDE VOC EMISSION REDUCTIONS OF THE FIVE MODEL PLANT CATEGORIES UNDER MODIFIED REGULATORY ALTERNATIVE III FOR TEN YEARS

Model plant category	Year	Cumulative nationwide emissions through each year, Mg VOC Regulatory Alternative I	Cumulative nationwide emissions through each year, Mg VOC Regulatory Alternative modified III	Cumulative nationwide emission reduction through each year under modified Regulatory Alternative III[a], Mg VOC
Small commercial	1	44-104	44-104	0
	2	132-312	132-312	0
	3	264-624	264-624	0
	4	440-1,040	440-1,040	0
	5	660-1,560	660-1,560	0
	6	924-2,180	924-2,180	0
	7	1,232-2,910	1,230-2,910	0
	8	1,580-3,740	1,580-3,740	0
	9	1,980-4,680	1,980-4,680	0
	10	2,420-5,720	2,420-5,720	0
Medium commercial	1	704-1,630	704-1,630	0
	2	2,110-4,890	2,110-4,890	0
	3	4,220-9,770	4,220-9,770	0
	4	7,040-16,300	7,040-16,300	0
	5	10,600-24,400	10,600-24,400	0
	6	14,800-34,200	14,800-34,200	0
	7	19,700-45,600	19,700-45,600	0
	8	25,300-58,600	25,300-58,600	0
	9	31,700-73,300	31,700-73,300	0
	10	38,700-89,600	38,700-89,600	0
Large commercial	1	616-1,420	103-714	513-706
	2	1,850-4,270	310-2,140	1,540-2,130
	3	3,690-8,540	620-4,290	3,070-4,250
	4	6,160-14,200	1,030-7,140	5,130-7,060
	5	9,240-21,400	1,550-10,700	7,690-10,700
	6	12,900-29,900	2,170-15,000	10,730-14,900
	7	17,200-39,900	2,900-20,000	14,300-19,900
	8	22,200-51,300	3,720-25,700	18,500-25,600
	9	27,700-64,100	4,650-32,100	23,100-32,000
	10	33,900-78,300	5,690-39,300	28,200-39,000
Small industrial	1	85-202	15-101	70-101
	2	254-606	44-303	210-303
	3	508-1,210	88-607	420-603
	4	846-2,020	147-1,010	699-1,010
	5	1,270-3,030	221-1,520	1,050-1,510
	6	1,780-4,240	309-2,120	1,470-2,120
	7	2,370-5,650	412-2,830	1,960-2,820
	8	3,050-7,270	529-3,640	2,520-3,630
	9	3,810-9,090	662-4,550	3,150-4,540
	10	4,650-11,100	809-5,560	3,840-5,540
Large industrial	1	787-1,830	112-888	675-942
	2	2,360-5,500	336-2,660	2,020-2,840
	3	4,720-11,000	672-5,330	4,050-5,670
	4	7,870-18,300	1,120-8,880	6,750-9,420
	5	11,800-27,500	1,680-13,300	10,100-14,200
	6	16,500-38,500	2,350-18,600	14,200-19,900
	7	22,000-51,300	3,140-24,900	18,900-26,400
	8	28,300-66,000	4,030-32,000	24,300-34,000
	9	35,400-82,400	5,040-40,000	30,400-42,400
	10	43,300-101,000	6,160-48,800	37,100-52,200
Total industry	1	2,240-5,190	978-3,440	1,260-1,750
	2	6,710-15,600	2,930-10,300	3,780-5,300
	3	13,400-31,100	5,860-20,600	7,540-10,500
	4	22,400-51,900	9,780-34,400	12,600-17,500
	5	33,600-77,900	14,700-51,500	18,900-26,400
	6	46,900-109,000	20,600-72,100	26,300-36,900
	7	62,500-145,000	27,400-96,200	35,100-48,800
	8	80,400-187,000	35,200-124,000	45,200-63,000
	9	101,000-234,000	44,000-155,000	57,000-79,000
	10	123,000-286,000	53,800-189,000	69,200-97,000

[a] Small and medium commercial facilities do not show any emission reductions because these facilities are exempted from the requirement of installing recovery dryers.

D.2.2 Water Quality Impacts

Water pollution impacts in petroleum solvent dry cleaning plants result from the production of wastewater that may contain residual solvent. The only source producing an increase in the quantity of wastewater due to the implementation of modified Regulatory Alternative III is the recovery dryer (see Section 7.2 for a more thorough discussion of wastewater from a recovery dryer). The annual increase in water pollution in the five model plants due to the installation of recovery dryers under modified Alternative III relative to Alternative I (baseline) is given in Table D-5. The annual water pollution impacts are expressed as the annual increase in the mass of solvent-laden wastewater and as the annual increase in solvent in the wastewater. The increased mass of solvent-laden water is based on the most recent and complete test data that indicate a recovery dryer recovered water rate of 3.29 kilograms of water per 100 kilograms of articles cleaned. The increase in the mass of solvent in sewered water is based on the estimated maximum solubility of solvent in water (see Chapter 7 for additional information). The quantity of petroleum solvent contained in the sewered wastewater from the recovery dryer is insignificant in comparison to the total plant annual quantity of solvent-laden wastewater disposed. Both the quantity of solvent itself and the solvent-laden wastewater disposed are a function of the model plant throughput. Because small and medium commercial model plants are exempted from mandatory recovery dryer installation under modified Alternative III, there are no increases in the mass of solvent-laden wastewater or solvent in the disposed wastewater. The large industrial model plant produces the largest increase in solvent-laden wastewater (20.9 megagrams per year) and solvent in the wastewater (1.57 kilograms per year) because this model plant source category contains the most recovery dryers. The large commercial model plant produces the lowest increase in solvent-laden wastewater (2.70 megagrams per year) and solvent in the wastewater (0.20 kilgrams per year) because this category contains the fewest recovery dryers of the three large model plant categories.

Table D-5. ANNUAL WATER POLLUTION IMPACTS OF EMISSION CONTROL IN FIVE MODEL PLANTS[a]

Model plant (throughput in Kg/yr)	Annual increase in mass of solvent-laden wastewater disposed in sewer (Mg/yr)	Annual increase in solvent in disposed wastewater (Kg/yr)
Small commercial[b] (14,000)	0	0
Medium commercial[b] (32,000)	0	0
Large commercial (82,000)	2.70	0.20
Small industrial (182,000)	5.98	0.45
Large industrial (635,000)	20.9	1.57

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[a] Water impacts due only to installation of recovery dryers under modified Regulatory Alternative III relative to Regulatory Alternative I.

[b] Plants are exempted from the requirement of installing recovery dryers and consequently, have no wastewater impacts.

The cumulative nationwide water impacts resulting from modified Alternative III are given in Table D-6. These were derived by multiplying the annual water impacts for each individual model plant given in Table D-5 by the appropriate cumulative number of affected plants existing through each year given in Table D-3. Of the three model plant categories required to install recovery dryers, the large commercial model plant category has the lowest increase in cumulative nationwide ten-year water impacts whereas, the large industrial category has the greatest. Ten year cumulative nationwide increases in solvent-laden wastewater are 6,980 megagrams and 9,200 megagrams in the large commercial and large industrial model plant categories, respectively.

D.2.3 Solid Waste Impacts

There are insignificant solid waste impacts in the five model plants due to the implementation of modified Regulatory Alternative III. Recovery dryers do not produce an increase in solid waste in comparison to standard dryers. Although the operational and maintenance procedures may result in reduced industry wide solid waste emissions, these reductions are unquantifiable.

D.2.4 Energy Impacts

Annual energy impacts of Alternative I and modified Alternative III for the five model plants are given in Table D-7. These annual impacts are based on plant steam and electricity consumption due to use of a standard dryer under Alternative I and on the use of a recovery dryer with a refrigerated chiller under modified Alternative III. These energy impacts do not include the energy consumption of other affected equipment. Dryer energy consumption is determined by converting the energy costs (see Tables D-10 through D-12) of both steam and electricity into common units of work (gigajoules). The overall consumption of energy increases proportionally with increased model plant throughput, with recovery dryers using significantly less energy than standard dryers. The largest annual energy consumption is produced by the large industrial model plant due to the relatively large throughput capacity of this category. The large industrial model plant consumes 4,620 gigajoules per year of energy under Alternative I and 1,710 gigajoules per year under modified Alternative III. An energy consumption reduction of 2,910 gigajoules per year in the large industrial model plant results

Table D-6. CUMULATIVE NATIONWIDE WATER IMPACTS OF EMISSION CONTROL IN MODEL PLANTS UNDER MODIFIED REGULATORY ALTERNATIVE III FOR TEN YEARS[a]

Model plant	Year	Increase in mass of solvent-laden wastewater (Mg)	Increase in solvent in disposed wastewater (Kg)
Large commercial	1	127	9.40
	2	381	28.2
	3	761	56.4
	4	1,270	94.0
	5	1,900	141
	6	2,660	197
	7	3,550	263
	8	4,570	338
	9	5,710	423
	10	6,980	517
Small industrial	1	17.9	1.35
	2	53.8	4.05
	3	108	8.10
	4	179	13.5
	5	269	20.3
	6	377	28.4
	7	502	37.8
	8	646	48.6
	9	807	60.8
	10	987	74.3
Large industrial	1	167	12.6
	2	502	37.7
	3	1,000	75.4
	4	1,670	126
	5	2,510	188
	6	3,510	264
	7	4,680	352
	8	6,020	452
	9	7,520	365
	10	9,200	691
Total industry	1	312	23.4
	2	937	70.0
	3	1,870	140
	4	3,120	234
	5	4,680	349
	6	6,550	555
	7	8,730	653
	8	11,200	839
	9	14,000	1,050
	10	17,200	1,280

[a] Water impacts due only to installation of recovery dryers.

Table D-7. ANNUAL ENERGY IMPACTS OF TWO REGULATORY ALTERNATIVES IN FIVE MODEL PLANTS[a]

Model plant (throughput in Kg/yr)	Annual energy consumption in GJ/yr		Modified Regulatory Alternative III energy reduction in GJ/yr
	Alternative I	Modified Alternative III	
Small commercial (14,000)	48.5	48.5	0[b]
Medium commercial (32,000)	127	127	0[b]
Large commercial (82,000)	429	178	251
Small industrial (182,000)	1,250	485	765
Large industrial (635,000)	4,620	1,710	2,910

[a] Energy consumption is the sum of electrical and steam consumption, and include only that consumed by dryers.

[b] Plants are exempted from mandatory installation of recovery dryers and, consequently, have no energy impacts under modified Regulatory Alternative III.

from the implementation of modified Alternative III relative to Alternative I. Small and medium commercial model plants are both exempt from recovery dryer requirements under modified Alternative III, and consequently, have no energy impacts resulting from the implementation of modified Alternative III.

Cumulative nationwide energy impacts in the five model plant categories due to modified Alternative III are presented in Table D-8 for the ten years following proposal of the standards. The cumulative nationwide energy impacts were derived by multiplying the individual model plant energy consumptions given in Table D-7 by the appropriate cumulative number of affected plants existing through each year given in Table D-3. The cumulative annual nationwide energy consumption in both the small and medium commercial model plant categories are identical under Alternative I and modified Alternative III because these categories are exempted from modified Alternative III recovery dryer requirements. Consequently, there are no cumulative nationwide energy consumption reductions given for the small and medium commercial model plant categories. The large industrial model plant category consumes the largest ten-year cumulative nationwide amount of energy (2.030,000 gigajoules under Alternative I and 752,000 gigajoules under modified Alternative III). Consequently, the largest cumulative ten-year energy consumption reduction (1,280,000 gigajoules) occurs in the large industrial model plant category due to the implementation of modified Alternative III. The cumulative ten-year nationwide energy consumption for the total industry is 3,350,000 gigajoules under Alternative I and 1,290,000 gigajoules under modified Alternative III. Modified Alternative III produces a cumulative nationwide ten-year energy consumption reduction of 2,060,000 gigajoules in the aggregate industry.

In addition to decreasing the amount of electricity and steam consumed, modified Alternative III also provides for the recovery of petroleum solvent, which is a vital energy resource composed primarily of C_8 to C_{12} hydrocarbons similar to kerosene. The volumetric reductions of petroleum solvent consumed in the three impacted model plants resulting from VOC emission control are presented in Table D-9. The petroleum solvent consumption reductions were derived by converting the megagrams per year VOC emission reductions given in Table D-2 to liters of petroleum

Table D-8. CUMULATIVE NATIONWIDE ENERGY IMPACTS IN FIVE MODEL PLANT CATEGORIES UNDER MODIFIED REGULATORY ALTERNATIVE III FOR TEN YEARS

Model plant category	Year	Cumulative nationwide energy consumption (GJ)		Cumulative nationwide energy reduction due to modified Regulagory Alternative III, (GJ)
		Regulatory Alternative		
		I	modified III	
Small commercial	1	970	970	0
	2	2910	2910	0
	3	5820	5820	0
	4	9700	9700	0
	5	14600	14600	0
	6	20400	20400	0
	7	27200	27200	0
	8	34900	34900	0
	9	43700	43700	0
	10	53400	53400	0
Medium commercial	1	17500	17500	0
	2	52600	52600	0
	3	105000	105000	0
	4	175000	175000	0
	5	263000	263000	0
	6	368000	368000	0
	7	491000	491000	0
	8	631000	631000	0
	9	789000	789000	0
	10	964000	964000	0
Large commercial	1	20200	8370	11800
	2	60500	25100	35400
	3	121000	50200	70800
	4	202000	83700	118000
	5	303000	126000	177000
	6	423000	176000	248000
	7	565000	234000	330000
	8	726000	301000	425000
	9	907000	377000	431000
	10	1110000	460000	649000
Small industrial	1	3750	1460	2300
	2	11300	4370	6890
	3	22500	8730	13800
	4	37500	14600	23000
	5	56300	21800	34400
	6	78800	30600	48200
	7	105000	40700	64300
	8	135000	52400	82600
	9	169000	65500	103000
	10	206000	80000	126000
Large industrial	1	37000	13700	23300
	2	111000	41000	69800
	3	222000	82100	140000
	4	370000	137000	233000
	5	554000	205000	349000
	6	776000	287000	489000
	7	1040000	383000	652000
	8	1340000	494000	841000
	9	1660000	616000	1050000
	10	2030000	752000	1280000
Total industry	1	60900	23500	37400
	2	187000	70500	112000
	3	365000	141000	224000
	4	609000	235000	374000
	5	913000	353000	561000
	6	1280000	494000	785000
	7	1700000	658000	1050000
	8	2200000	848000	1350000
	9	2740000	1060000	1680000
	10	3350000	1290000	2060000

Table D-9. REDUCTION IN VOLUME OF PETROLEUM SOLVENT CONSUMED IN THE THREE IMPACTED MODEL PLANTS

Model plant (throughput in kg/yr)	Modified Alternative III petroleum solvent consumption reduction, ℓ/yr
Large commercial (82,000)	14,500 - 20,100 (15,900)[a]
Small industrial (182,000)	31,100 - 44,800 (35,100)[b], (35,200)
Large industrial (635,000)	112,000 - 157,000 (123,000)

[a] Values in parenthesis are based on nominal VOC emission rates.

[b] Small industrial plants sometimes omit filtration with heavy soil loading.

solvent per year. As Table D-9 indicates, the large industrial plant experiences the greatest reduction in annual solvent consumption, and the total annual solvent consumption reduction ranges from 158,000 to 222,000 liters solvent per year.

D.3 COST IMPACTS

A thorough discussion of the data base and the methodology for deriving the capital and annualized costs is presented in Chapter 8 for Alternatives I, II, and III in the five model plants. This section, therefore, only discusses the cost impacts associated with the implementation of modified Regulatory Alternative III relative to Regulatory Alternative I. The cost difference between Alternative I and modified Alternative III is based on the use of a refrigerated chiller for cooling water supply in the recovery dryer, in addition to the cost difference resulting from the use of a recovery dryer instead of a standard dryer. The capital and annualized costs in the three impacted model plants under Alternative I and modified Alternative III are presented in Tables D-10 through D-12. The capital costs are greatest in the large industrial model plant under both Alternative I ($85,340) and modified Alternative III ($176,880). All costs for small and medium commercial model plants are the same under Alternative I and modified Alternative III because both are exempt from mandatory recovery dryer installation under modified Alternative III. Total annualized operating costs are also greatest in the large industrial model plant under Alternative I and modified Alternative III. Table D-13 summarizes the annualized cost differences between Alternative I and modified Alternative III from Tables D-10 through D-12. Table D-13 also summarizes the emissions reductions and cost effectiveness of control alternatives in the three impacted model plants. All of the model plants impacted under modified Alternative III have an annualized cost savings relative to Alternative I. The large industrial model plant has the greatest annualized cost savings ($39,300 to $57,800) resulting from the implementation of modified Alternative III. The modified Alternative III cost effectiveness is a savings ($470 to $490 per megagram emission reduction) in the large industrial model plant. The small industrial model plant produces the

Table D-10. CAPITAL AND ANNUALIZED COSTS OF CONTROLS IN A LARGE COMMERCIAL MODEL PLANT
(costs are in thousands of first quarter 1981 dollars)

Cost parameters	Regulatory Alternatives	
	I	modified III
Capital costs[d]		
Equipment	5.13	18.73
Taxes, freight, and instrumentation	0.92	3.37
Direct and indirect installation	0.39	1.40
Total capital costs	6.44	23.50
Annualized costs		
Operating costs		
Steam	3.09	0.89
Electricity	0.19	0.96
Operating labor	3.22	3.22
Annual maintenance (labor and materials)	0.83	0.83
Subtotal, direct costs	7.33	5.90
Capital charges		
Capital recovery	0.68	2.49
Administration, taxes, and insurance	0.26	0.94
Subtotal, indirect costs	0.94	3.43
Total operating costs and capital charges	8.27	9.33
Recovered solvent value	0	(6.11-8.50)
Total annualized costs	8.27	0.83-3.22
Difference from baseline total control costs	0	(5.05-7.44)
Total annualized cost with cooling tower	b	(0.12)-2.27
Difference from baseline total control costs with cooling tower	b	(6.00-8.39)
Total annualized cost with no additional cooling water equipment	b	(0.45)-1.94
Difference from baseline total control costs with no additional cooling water equipment	b	(6.33-8.72)
Total emission reduction for each control alternative in Mg VOC per year	0	10.9-15.2
Total cost effectiveness for each control alternative in thousands of dollars per Mg of VOC emission reduction[c,d]	b	(0.46-0.49)
Total cost effectiveness with a cooling tower	b	(0.55-0.56)
Total cost effectiveness with no additional cooling water equipment	b	(0.57-0.58)

[a] Numbers in parenthesis represent thousands of dollars saved.

[b] Not applicable.

[c] Cost effectiveness is defined as the difference between baseline and the given regulatory alternative total annualized cost per megagram of emission reduction between baseline VOC emissions and that of the given control alternative.

[d] Modified Regulatory Alternative III costs include capital and annualized costs of both recovery dryer and refrigerated chiller.

Table D-11. CAPITAL AND ANNUALIZED COSTS OF CONTROLS IN A SMALL INDUSTRIAL MODEL PLANT
(costs are in thousands of first quarter 1981 dollars)

Cost parameters	Regulatory Alternatives	
	I	modified III
Capital costs[d]		
Equipment	15.39	53.05
Taxes, freight, and instrumentation	2.77	9.55
Direct and indirect installation	1.15	3.98
Total capital costs	19.31	66.58
Annualized costs		
Operating costs		
Steam	9.05	2.60
Electricity	0.54	2.24
Operating labor	5.58	5.58
Annual maintenance (labor and materials)	2.59	2.59
Subtotal, direct costs	17.76	13.01
Capital charges		
Capital recovery	2.05	7.06
Administration, taxes, and insurance	0.77	2.67
Subtotal, indirect costs	2.82	9.73
Total operating costs and capital charges	20.58	22.74
Recovered solvent value	0	(13.56-18.86)
Total annualized costs	20.58	3.88-9.18
Difference from baseline total control costs	0	(11.40-16.70)
Total annualized cost with cooling tower	b	2.10-7.40
Difference from baseline total control costs with cooling tower	b	(13.18-18.48)
Total annualized cost with no additional cooling water equipment	b	1.24-6.54
Difference from baseline total control costs with no additional cooling water equipment	b	(14.04-19.34)
Total emission reduction for each control alternative in Mg VOC per year	0	24.2-33.7
Total cost effectiveness for each control alternative in thousands of dollars per Mg of VOC emission reduction[c,d]	b	(0.47-0.50)
Total cost effectiveness with a cooling tower	b	(0.54-0.55)
Total cost effectiveness with no additional cooling water equipment	b	(0.57-0.58)

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[a] Numbers in parenthesis represent thousands of dollars saved.

[b] Not applicable.

[c] Cost effectiveness is defined as the difference between baseline and the given regulatory alternative total annualized cost per megagram of emission reduction between baseline VOC emissions and that of the given control alternative.

[d] Modified Regulatory Alternative III costs include capital and annualized costs of both recovery dryer and refrigerated chiller.

Table D-12. CAPITAL AND ANNUALIZED COSTS OF CONTROLS IN A LARGE INDUSTRIAL MODEL PLANT
(costs are in thousands of first quarter 1981 dollars)

Cost parameters	Regulatory Alternatives	
	I	modified III
Capital costs[d]		
Equipment	68.00	140.94
Taxes, freight, and instrumentation	12.24	25.37
Direct and indirect installation	5.10	10.57
Total capital costs	85.34	176.88
Annualized costs		
Operating costs		
Steam	31.00	9.20
Electricity	7.27	7.82
Operating labor	10.11	20.84
Annual maintenance (labor and materials)	1.73	6.91
Subtotal, direct costs	50.11	44.77
Capital charges		
Capital recovery	9.05	18.76
Administration, taxes, and insurance	3.41	7.08
Subtotal, indirect costs	12.46	25.84
Total operating costs and capital charges	62.57	70.61
Recovered solvent value	0	(47.30-65.79)
Total annualized costs	62.57	4.82-23.31
Difference from baseline total control costs	0	(39.26-57.75)
Total annualized cost with cooling tower	b	(1.50)-16.99
Difference from baseline total control costs with cooling tower	b	(45.58-64.07)
Total annualized cost with no additional cooling water equipment	b	(3.60)-14.89
Difference from baseline total control costs with no additional cooling water equipment	b	(47.68-66.17)
Total emission reduction for each control alternative in Mg VOC per year	0	84.5-118
Total cost effectiveness for each control alternative in thousands of dollars per Mg of VOC emission reduction[c,d]	b	(0.47-0.49)
Total cost effectiveness with a cooling tower	b	(0.54-0.55)
Total cost effectiveness with no additional cooling water equipment	b	(0.56-0.57)

[a] Numbers in parenthesis represent thousands of dollars saved.

[b] Not applicable.

[c] Cost effectiveness is defined as the difference between baseline and the given regulatory alternative total annualized cost per megagram of emission reduction between baseline VOC emissions and that of the given control alternative.

[d] Modified Regulatory Alternative III costs include capital and annualized costs of both recovery dryer and refrigerated chiller.

Table D-13. SUMMARY OF THE INCREMENTAL ANNUALIZED COST, EMISSIONS REDUCTION, AND COST EFFECTIVENESS FROM BASELINE TO REGULATORY ALTERNATIVE III IN FIVE MODEL PLANTS[a]
(costs in first quarter 1981 dollars)

Model Plants	Incremental annualized cost from baseline controls[b] (in thousands of dollars)	Emission reduction $\left(\frac{\text{Mg VOC}}{\text{yr}}\right)$	Cost effectiveness of control alternatives $\frac{\text{incremental annualized cost in \$}10^3}{\text{Mg emission reduction}}$
Small commercial	NA[d]	NA	NA
Medium commercial	NA	NA	NA
Large commercial	(5.05-7.44)[c]	10.9-15.2	(0.46-0.49)
Small industrial	(11.40-16.70)	24.2-33.7	(0.47-0.50)
Large industrial	(39.26-57.75)	84.5-118	(0.47-0.49)

[a] Regulatory Alternative II emission reductions and annualized costs impacts are not quantifiable and are, consequently, not presented.

[b] Annualized cost difference for modified Alternative III is based on recovery dryer cooling water being supplied by a refrigerated chiller.

[c] Numbers in parentheses represent thousands of dollars saved.

[d] NA = not applicable.

greatest cost effectiveness savings ($470 to $500 per megagram of emission reduction) because it produces a relatively high annualized cost savings ($11,400 to $16,700) and is a relatively small source of emissions reductions (24.2 to 33.7 megagrams VOC per year).

The nationwide cost analyses of Regulatory Alternatives I and modified Alternative III in the three impacted model plant categories for the first five years after proposal and ten years after proposal are presented in Tables D-14 and D-15, respectively. The capital costs for modified Regulatory Alternative III for the aggregate industry exceed the five year Alternative I costs by $8,180,000 and the ten year Alternative I costs by $16,400,000. For the aggregate industry, cumulative annualized costs for modified Regulatory Alternative III were less than Regulatory Alternative I by $8,820,000 to $13,000,000 for five years and $32,200,000 to $47,400,000 for ten years. This net decrease in cumulative annualized costs results from the cost savings associated with the recovery of solvent under modified Regulatory Alternative III. The total cost effectiveness due to the implementation of modified Regulatory Alternative III for the aggregate industry ranges from $460 to $490 per megagram VOC emission reduction for both five and ten years.

Table D-14. NATIONWIDE COST ANALYSIS OF REGULATORY ALTERNATIVES IN THE THREE IMPACTED MODEL PLANT CATEGORIES PROJECTED FOR FIVE YEARS AFTER PROPOSAL (first quarter 1981 dollars)

	Regulatory Alternative I		Modified Regulatory Alternative III[a]			
Model plant category	Total capital cost ($\$10^3$)	Cumulative annualized cost ($\$10^3$)	Total capital cost ($\$10^3$)	Cumulative annualized cost ($\$10^3$)	Cumulative emission reduction (Mg VOC)	Total cost effectiveness[b] $\frac{\Delta\ \$10^3}{\text{Mg VOC}}$
Large commercial	1,510	5,830	5,520	585-2,270	7,690-10,700	(0.46-0.49)[c]
Small industrial	270	926	932	175-413	1,090-1,520	(0.47-0.50)
Large industrial	3,240	7,510	6,720	580-2,800	10,100-14,200	(0.47-049)
TOTAL	5,020	14,300	13,200	1,340-5,480	18,900-26,400	(0.46-0.49)

[a] Recovery dryer cooling water is supplied by a refrigerated chiller.

[b] Cost effectiveness defined as the difference between baseline (Alternative I) cumulative annualized cost and that of modified Alternative III, per megagram of cumulative VOC emission reduction.

[c] All numbers in parentheses are cost savings.

Table D-15. NATIONWIDE COST ANALYSIS OF REGULATORY ALTERNATIVES IN THE THREE IMPACTED MODEL PLANT CATEGORIES PROJECTED FOR TEN YEARS AFTER PROPOSAL (first quarter 1981 dollars)

	Regulatory Alternative I		Modified Regulatory Alternative III[a]			
Model plant category	Total capital cost ($$10^3$)	Cumulative annualized cost ($$10^3$)	Total capital cost ($$10^3$)	Cumulative annualized cost ($$10^3$)	Cumulative emission reduction (Mg VOC)	Total cost effectiveness[b] $\frac{\Delta \$10^3}{\text{Mg VOC}}$
Large commercial	3,030	21,400	11,000	2,150-8,320	28,200-39,300	(0.46-0.49)[c]
Small industrial	521	3,400	1,800	640-1,520	3,990-5,560	(0.47-0.50)
Large industrial	6,660	27,500	13,800	2,120-10,300	37,200-51,900	(0.47-0.49)
TOTAL	10,200	52,300	26,600	4,910-20,100	69,400-96,800	(0.46-0.49)

[a] Recovery dryer cooling water is supplied by a refrigerated chiller.

[b] Cost effectiveness defined as the difference between baseline (Alternative I) cumulative annualized cost and that of modified Alternative III, per megagram of VOC cumulative emission reduction.

[c] All numbers in parentheses are cost savings.